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beml

NEW FRONTIERS. NEW DREAMS

SHOP MANUAL

BS(A)6D170-1 SERIES DIESEL ENGINE

BEML LIMITED

MYSORE, INDIA.

CONTENTS

IMPORTANT SAFETY NOTICE

Proper service and repair is extremely important for the safe operation of your machine. The service and repair techniques recommended by BEML and decribed in this manual are both effective and safe methods of operation. Some of these operations require the use of tools specially designed by BEML for the purpose.

To prevent injury to workers, the symbol ⚠ and ⚠ are used to mark safety precautions in this manual. The cautions accompanying these symbols should always be followed carefully. If any dangerous situation arises or may possibly arise, first consider safety, and take the necessary actions to deal with the situation.

SAFETY

GENERAL PRECAUTIONS

Mistakes in operation are extremely dangerous. Read the Operation and Maintenance Manual carefully BEFORE operating the machine.

1. Before carrying out any greasing or repairs, read all the precautions given on the decals which are fixed to the machine.

2. When carriyng out any operation, always wear safety shoes and helmet. Do not wear loose work clothes, or clothes with buttons missing.

- Always wear safety glasses when hitting parts with a hammer.
- Always wear safety glasses when grinding parts with a grinder, etc.

3. If welding repairs are needed, always have a trained, experienced welder carry out the work. When carrying out welding work, always wear welding gloves, apron, glasses, cap and other clothes suited for welding work.

4. When carrying out any operation with two or more workers, always agree on the operating procedure before starting. Always inform your fellow workers before starting any step of the operation. Before starting work, hang UNDER REAIR signs on the controls in the operator's compartment.

5. Keep all tools in good condition and learn the correct way to use them.

6. Decide a place in the repair workshop to keep tools and removed parts. Always keep the tools and parts in their correct places. Always keep the work area clean and make sure that there is no dirt or oil on the floor. Smoke only in the areas provided for smoking. Never smoke while working.

PREPARATIONS FOR WORK

7. Before adding oil or making any repairs, part the machine on hard, level ground, and block the wheels or tracks to prevent the machine from moving.

8. Before starting work, lower blade, ripper, bucket or any other work equipment to the ground. If this is not possible, insert the safety pin or use blocks to prevent the work equipment from falling. In addition, be sure to lock all the control levers and hang warning signs on them.

9. When disassembling or assembling, support the machine with blocks, jacks or stands before starting work.

10. Remove all mud and oil from the steps or other places used to get on and off the machine. Always use the handrails, ladders or steps when getting on or off the machine. Never jump on or off the machine. If it is impossible to use the handrails, ladders or steps, use a stand to provide safe footing.

PRECAUTIONS DURING WORK

11. When removing the oil filler cap, drain plug or hydraulic pressure measuring plugs, loosen them slowly to prevent the oil from spurting out.
    Before disconnecting or removing components of the oil, water or air circuits, first remove the pressure completely from the circuit.

12. The water and oil in the circuits are hot when the engine is stopped, so be careful not to get burned. Wait for the oil and water to cool before carrying out any work on the oil or water circuits.

13. Before starting work, remove the leads from the battery. Always remove the lead from negative (-) terminal first.

14. When raising heavy components, use a hoist or crane.
    Check that the wire rope, chains and hooks are free from damage.
    Always use lifting equipment which has ample capacity.
    Install the lifting equipment at the correct places.
    Use a hoist or crane and operate slowly to prevent the component from hitting any other part.
    Do not work with any part still raised by the hoist or crane.

15. When removing covers which are under internal pressure or under pressure from a spring, always leave two bolts in position on opposite sides. Slowly release the pressure, then slowly loosen the bolts to remove.

16. When removing components, be careful not to break or damage the wiring. Damaged wiring may cause electrical fires.

17. When removing piping, stop the fuel or oil from spilling out. If any fuel or oi1 drips on to the floor, wipe it up immediately. Fuel or oil on the floor can cause you to slip, or can even start fires.

18. As a general rule, do not use gasoline to wash parts. In particular, use only the minimum of gasoline when washing electrical parts.

19. Be sure to assemble all parts again in their original places.
    Replace any damaged parts with new parts.
    - When installing hoses and wires, be sure that they will not be damaged by contact with other parts when the machine is being operated.

20. When installing high pressure hoses, make sure that they are not twisted. Damaged tubes are dangerous, so be extremely careful when installing tubes for high pressure circuits. Also, check that connecting parts are correctly installed.

21. When assembling or installing parts, always use the specified tightening torques. When installing protective parts such as guards, or parts which vibrate violently or rotate at high speed, be particularly careful to check that they are installed correctly.

22. When aligning two holes, never insert your fingers or hand. Be careful not to get your fingers caught in a hole.

23. When measuring hydraulic pressure, check that the measuring tool is correctly assembled before taking any measurements.

24. Take care when removing or installing the tracks of track-type machines.
    When removing the track, the track separates suddenly, so never let anyone stand at either end of the track.

FOREWORD

This shop manual has been prepared as an aid to improve the quality of repairs by giving the serviceman an accurate understanding of the product and by showing him the correct way to perform repairs and make judgements. Make sure you understand the contents of this manual and use it to full effect at every opportunity.

This shop manual mainly contains the necessary technical information for operations performed in a service workshop.

For ease of understanding, the manual is divided into chapters for each main group of components; these chapters are further divided into the following sections.

STRUCTURE AND FUNCTION

This section explains the structure and function of each component. It serves not only to give an understanding of the structure, but also serves as reference material for troubleshooting.

TESTING AND ADJUSTING

This section explains checks to be made before and after performing repairs, as well as adjust ments to be made at completion of the checks and repairs.
Troubleshooting charts correlating “Problems” to “Causes” are also included in this section.

DISASSEMBLY AND ASSEMBLY

This section explains the order to be followed when removing, installing, disassembling or assembling each component, as well as precautions to be taken for these operations.

MAINTENANCE STANDARD

This section gives the judgement standards when inspecting disassembled parts.

NOTICE

The specifications contained in this shop manual are subject to change at any time and without any advance notice. Contact your **beml** Regional Office for the latest information.

HOW TO READ THE SHOP MANUAL

VOLUMES

Shop manuals are issued as a guide to carrying out repairs. They are divided as follows:

Chassis volume : Issued for every machine model
Engine volume : Issued for each engine series.
Electrical volume : } Each issued as one volume to cover all models
Attachments volume : }

These various volumes are designed to avoid duplicating the same information. Therefore to deal with all repairs for any model, it is necessary that chassis, engine, electrical and attachment volumes are ready.

DISTRIBUTION AND UPDATING

Any additions, amendments or other changes will be sent to **beml** Regional office. Get the most upto-date information before you start any work.

FILING METHOD

1. See the page number on the bottom of the page. File the pages in correct order.
2. Following examples show how to read the page number.

Example.

12 - 10
- 12 - Unit number (1. Engine)
- 12 - Item number (2. Testing and Function)
- 10 - Consecutive page number

3. Additional pages: Additional pages are indicated by a hyphen (-) and number after the page number. File as in the example.
Example:

REVISED EDITION MARK (① ② ③ ...)

When a manual is revised, an edition mark is recorded on the bottom outside corner of the pages.

REVISIONS

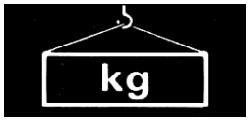
Revised pages are shown at the LIST OF REVISED PAGES on the between the title page and SAFETY page.

SYMBOLES

So that the shop manual can be of ample practical use, important places for safety and quality are marked with the following symbols.

Symbol	Item	Remarks
	Safety	Special safety precautions are necessary when performing the work.
		Extra special safety precautions are necessary when performing the work because it is under internal pressure.
★	Caution	Special technical precautions or other precautions for preserv ing standards are necessary when performing the work.
	Weight	Weight of parts or systems. Caution necessary when selecting hoisting wire, or when working posture is important, etc.
	Tighten- ing torque	Places that require special attention for the tightening torque during assembly.
	Coat	Places to be coated with adhesives and lubricants etc.
	Oil, water	Places where oil, water or fuel must be added, and the capacity.
	Drain	Places where oil or water must be drained, and quantity to be drained.

HOISTING INSTRUCTIONS



⚠ Heavy parts (25 kg or more) must be lifted with a hoist etc. In the **Disassembly and Assembly** section, every part weighing 25 kg or more is indicated clearly with the symbol 

1. If a part cannot be smoothly removed from the machine by hoisting, the following checks should be made:
- Check for removal of all bolts fastening the part to the relative parts.
- Check for existence of another part causing interference with the part to be removed.

2. Wire ropes

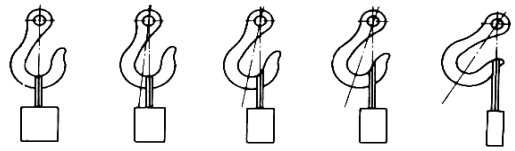
1) Use adequate ropes depending on the weight of parts to be hoisted, referring to the table below:

Wire ropes (Standard "Z" or"S" twist ropes without galvanizing)	
Rope diameter (mm)	Allowable load (tons)
10	1.0
11.2	1.4
12.5	1.6
14	2.2
16	2.8
18	3.6
20	4.4
22.4	5.6
30	10.0
40	18.0
50	28.0
60	40.0

The allowable load value is estimated to be one-sixth or one-seventh of the breaking strength of the rope used.

2) Sling wire ropes from the middle portion of the hook.
Slinging near the edge of the hook may cause the rope to slip off the hook during hoisting, and a serious accident can result.

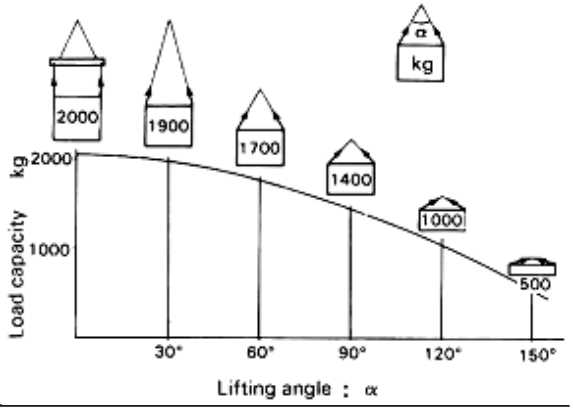
Hooks have maximum strength at the middle portion.

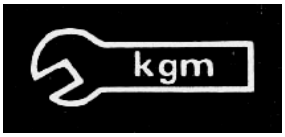


3) Do not sling a heavy load with one rope alone, but sling with two or more ropes symmetrically wound on to the load.

⚠ Slinging with one rope may cause turning of the load during hoisting, untwisting of the rope, or slipping of the rope from its original winding position on the load, which can result in a dangerous accident.

4) Do not sling a heavy load with ropes forming a wide hanging angle from the hook.
When hoisting a load with two or more ropes, the force subjected to each rope will increase with the hanging angles. The table below shows the variation of allowable load (kg) when hoisting is made with two ropes, each of which is allowed to sling up to 1000 kg vertically, at various hanging angles.
When two ropes sling a load vertically, up to 2000 kg of total weight can be suspended. This weight becomes 1000 kg when two ropes make a 120° hanging angle. On the other hand, two ropes are subjected to an excessive force as large as 4000 kg if they sling a 2000 kg load at a lifting angle of 150°.





STANDARD TIGHTENING TORQUE

1. STANDARD TIGHTENING TORQUE OF BOLTS AND NUTS

The following charts give the standard tightening torques of bolts and nuts. Exceptions are given in section of **"Disassembly and Assembly**

Thread diameter of bolt (mm)	width across flat (mm)	bcml (T) kgm	bcml (T) Nm
6	10	1.35±0.15	13.2±1.4
8	13	3.2±0.3	31.4±2.9
10	17	6.7±0.7	65.7±6.8
12	19	11.5±1.0	112±9.8
14	22	18.0±2.0	177±1.9
16	24	28.5±3	279±29
18	27	39±4	383±39
20	30	56±6	549±58
22	32	76±8	745±78
24	36	94.5±10	927±98
27	41	135±15	1320±140
30	46	175±20	1720±190
33	50	225±25	2210±240
36	55	280±30	2750±290
39	60	335±35	3280±340

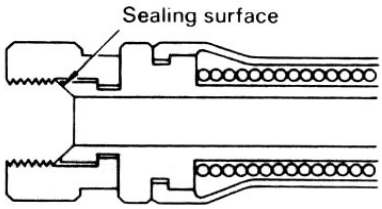
This torque table does not apply to the bolts with which nylon packings or other non-ferrous metals washers are to be used, or which require tightening to otherwise specified torque.

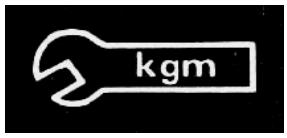
★ **Nm (newton meter): 1 Nm = 0.1 kgm**

2. TIGHTENING TORQUE OF SPLIT FLANGE BOLTS

Use these torques for split flange bolts.

Thread diameter of bolt (mm)	Width across flats (mm)	Tightening torque kgm	Tightening torque Nm
10	14	6.7±0.7	65.7±6.8
12	17	11.5±1	112±9.8
16	22	28.5±3	279±29



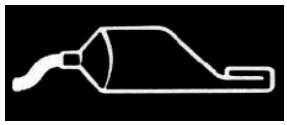


3. TIGHTENING TORQUE FOR NUTS OF FLARED

Use these torques for nut part of flared.

Thread diameter of nut part (mm)	width across flats of nut part (mm)	Tightening torque	
		kgm	Nm
14	19	2.5±0.5	24.5±4.9
18	24	5±2	49±19.6
22	27	8±2	78.5±19.6
24	32	14±3	137.3±29.4
30	36	18±3	176.5±29.4
33	41	20±5	196.1±49
36	46	25±5	245.2±49
42	55	30±5	294.2±49

COATING MATERIALS



The recommended coating materials prescribed in **beml** Shop Manuals are listed below.

Nomenclature	BEML code	Applications
Adhesives	LT-1A	Used to apply rubber pads, rubber gaskets, and cork plugs
	LT-1B	Used to apply resin, rubber, metallic and non-metallic parts when a fast, strong seal is needed
	LT-2*	Preventing bolts, nuts and plugs from loosening and leaking oil.
	LT-3	Provides an airtight, electrically insulating seal. Used for aluminum surfaces.
	LT-4	Used to coat plugs (plate shaped, bowl shaped) and holes, and mating portion of shaft.
Sealant gasket	LG-1	Used with gaskets and packings to increase sealing effect.
	LG-3	Heat-resistant gasket for precombustion chambers and exhaust piping.
	LG-4	Used by itself on mounting surfaces on the final drive and transmission cases. (Thickness after tightening: 0.07 - 0.08 mm)
	LG-5	Used by itself to seal grease fittings, tapered screw fittings and tapered screw fittings in hydraulic circuits of less than 50 mm in diameter.
	LG-6	Silicon base type used in combination with LG-1 and LG-4.
	LG-7	Has a shorter curing time than LG-6, and is easier to peel off.
Antifriction compound (Lubricant including molybdenum disulfide)	LM-P	Applied to bearings and taper shafts to facilitate press-fittings and to prevent sticking, burning or rusting.
Grease (Lithium grease)	G2-L1 -	Applied to bearings, sliding parts and oil seals for lubrication, rust prevention and facilitation of assembling work.
Vaseline		Used for protecting battery electrode terminals from corrosion.

*LT-2 is also called LOCTITE in the shop manuals.

ELECTRIC

ELECTRIC WIRE CODE

In the wiring diagrams, various colors and symbols are employed to indicate the thickness of wires.
This wire code table will help you understand WIRING DIAGRAMS.
Example: 5WB indicates a cable having a nominal number 5 and white coating with black stripe.

CLASSIFICATION BY THICKNESS

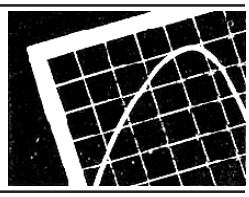
Nominal number	Copper Wire			Cable O.D (mm)	Current rating (A)	Applicable circuit
	Number strands	Dia.of strands (mm)	Cross section (mm^2)			
0.85	11	0.32	0.88	2.4	12	Starting,lighting,signal etc.
2	26	0.32	2.09	3.1	20	Lighting,signal etc.
5	65	0.32	5.23	4.6	37	Charging and signal
15	84	0.45	13.36	7.0	59	Starting (Glow plug)
40	85	0.80	42.73	11.4	135	Starting
60	127	0.80	63.84	13.6	178	Starting
100	217	0.80	109.1	17.6	230	Starting

CLASSIFICATION BY COLOR AND CODE

Priority	Circuits / Classification		Charging	Ground	Starting	Lighting	Instrument	Signal	Other
1	Primary	Code	W	B	B	R	Y	G	L
		Color	White	Black	Black	Red	Yellow	Green	Blue
2	Auxiliary	Code	WR	-	BW	RW	YR	GW	LW
		Color	White & red	-	Black & White	Red & White	Yellow &Red	Green & White	Blue & White
3		Code	WB	-	BY	RB	YB	GR	LR
		Color	White & Black	-	Black & Yellow	Red & Black	Yellow & Black	Green & Red	Blue & Red
4		Code	WL	-	BR	RY	YG	GY	LY
		Color	White & Blue	-	Black & Red	Red & Yellow	Yellow & Green	Green & Yellow	Blue & Yellow
5		Code	WG	-	-	RG	YL	(GB)	(LB)
		Color	White & Green	-	-	Red & Green	Yellow & Blue	(Green & Black)	(Blue & Black)
6		Code	-	-	-	RL	YW	(GL)	-
		Color	-	-	-	Red & Blue	Yellow & White	(Green & Blue)	-

ENGINE

11 GENRAL



SPECIFICATIONS

Engine model			BS6D170-1	
Applicable machine			BD155 / BP70	BD355/BD355X/BP100
Number of cylinder - Bore x Stroke		mm	6 - 170 x 170	
Total piston displacement		cc	23,150	
Firing order			1 - 5 - 3 - 6 - 2 - 4	
Dimensions	Overall length	mm	1,873	1,873
	Overall width	mm	1,190	1,265
	Overall height (Excluding exhaust pipe)	mm	1,922	1,922
	Overall height (Including exhaust pipe)	mm	-	-
Performance	Flywheel horsepower	HP/rpm	320/2,000	410/2,000
	Maximum torque	kgm/rpm	144/1,400	176/1,400
	High idling	rpm	2,200	2,200
	Low idling	rpm	650	650
	Minimum fuel consumption ratio	g/HP.h	168	164
Dry weight		kg	2,620	2,700
Fuel pump			Bosch PE-PD type	
Governor			Bosch RSUV centrifugal, all-speed type	
Lubricating oil amount (refill capacity)		ℓ	58 (43)	58 (43)
Coolant amount		ℓ	143	163
Aternator			24V, 35A (STD) 24V, 50A (OP.)	24V, 35A (STD) 24V, 50A (OP.)
Starting motor			24V, 11KW x 1	24V, 11KW x 1
Battery			12V, 200Ah x 2	12V, 200Ah x 2
Turbocharger			Komatsu KTR110/TEL-K36.	Komatsu KTR110/TEL-K36.
Air compressor			-	-
After cooler			-	-

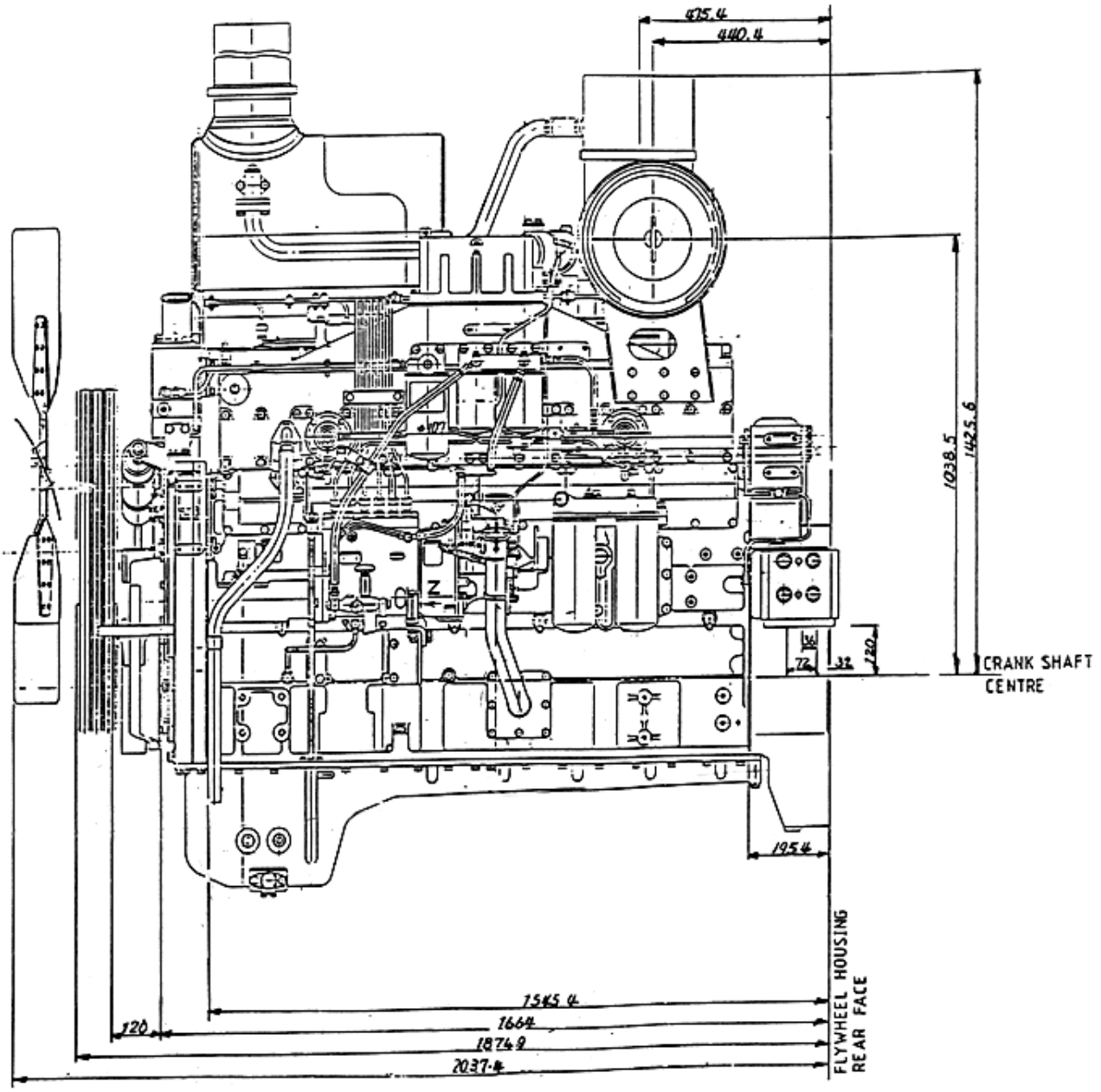
SPECIFICATIONS

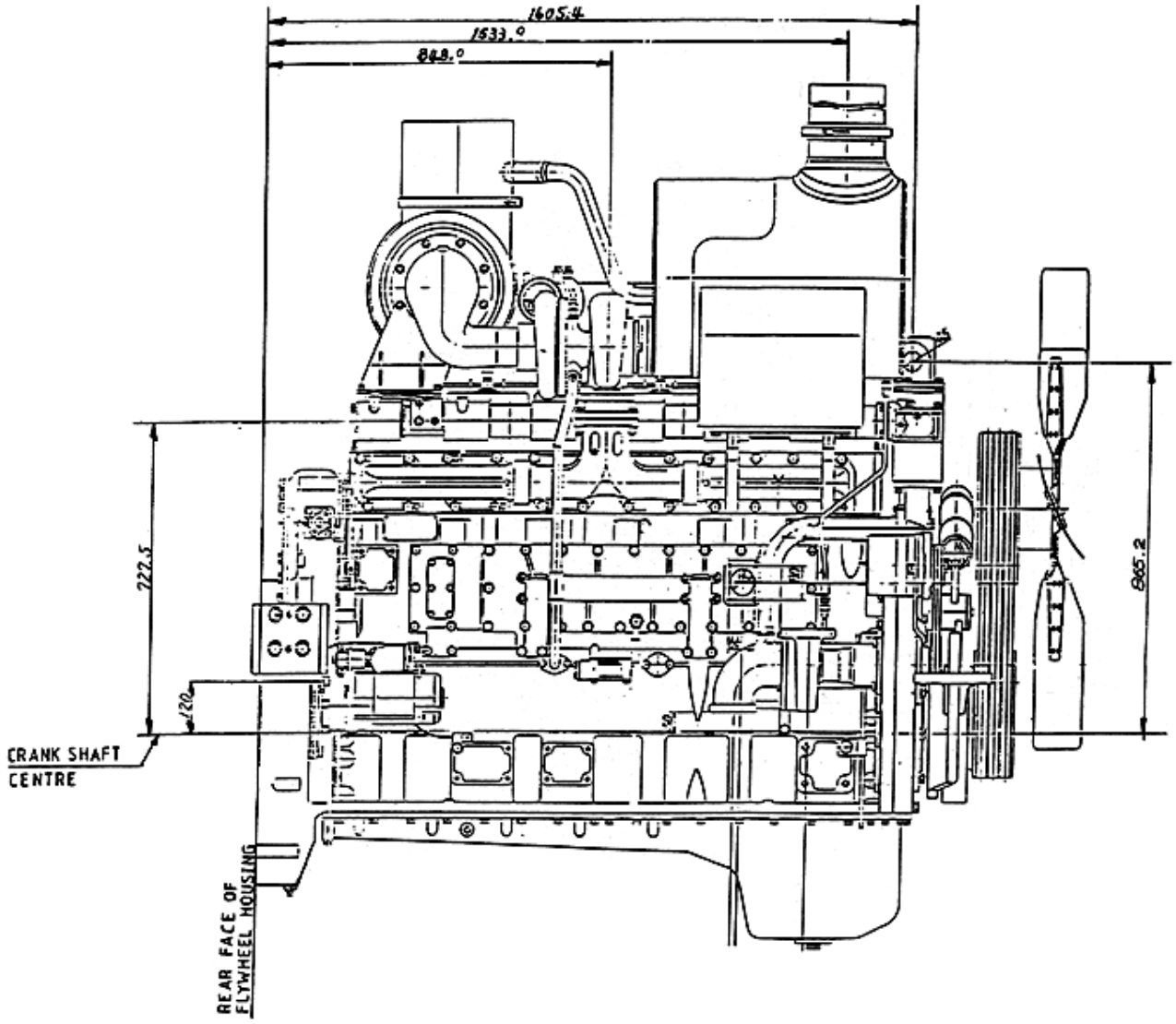
Engine model			BSA6D170-B-1
Applicable machine			BE1000
	Number of cylinder - Bore x Stroke	mm	6 - 170 x 170
	Total piston displacement	cc	23,150
	Firing order		1 - 5 - 3 - 6 - 2 - 4
Dimensions	Overall length	mm	2,373
	Overall width	mm	1,190
	Overall height (Excluding exhaust pipe)	mm	1,080
	Overall height (Including exhaust pipe)	mm	-
Performance	Flywheel horsepower	HP/rpm	542/1,700
	Maximum torque	kgm/rpm	260/1,300
	High idling	rpm	1,850 ± 50
	Low idling	rpm	675 ± 25
	Minimum fuel consumption ratio	g/HP.h	155
Dry weight		kg	2,555
Fuel pump			Bosch PE-P type
Governor			Bosch RSUV centrifugal, all-speed type
Lubricating oil amount (refill capacity)		ℓ	63 (51)
Coolant amount		ℓ	160
Aternator			24V, 50A
Starting motor			24V, 7.5kW x 2
Battery			12V, 200Ah x 2
Turbocharger			Komatsu KTR110
Air compressor			Diesel Kiki single cylinder double acting type
Other			With after cooler

Engine model			BSA6D170A-1		
Applicable machine			BH60	BH70	210M
No. of cylinders - Bore x Stroke		mm	6 - 170 x 170		
Total piston displacement		cc	23150		
Firing order			1 - 5 - 3 - 6 - 2 - 4		
Dimensions	Overall length	mm	2002		
	Overall width	mm	1137		
	Overall height (Including Fan)	mm	1678		
Performance	Flywheel horsepower	kW	504 @ 2100	33 @ 2100	483 @ 2100
		Bhp/rpm	675 @ 2100	725 @ 2100	647 @ 2100
	Max. torque	N.m/rpm	2750 @ 1400	2975 @ 1400	2618 @ 1400
		kgm/rpm	280 @ 1400	303 @ 1400	267 @ 1400
	High idling speed	rpm	2330 ~ 2400	2330 ~ 2400	2330 ~ 2400
	Low idling speed	rpm	900 ~ 950	900 ~ 950	900 ~ 950
	Min. fuel consumption ratio	g/kWh	212	211	215
Dry weight		kg	2660	2660	2635
Fuel pump			Bosch type		
Governor			mechanical		
Lubricating oil amount (refill capacity)		ℓ	64 (52)		
Coolant amount (Engine only)		ℓ	200	200	160
Aternator			24V, 50A		
Starting motor			24V, 7.5 kW x2		
Battery			12V, 200Ah x 2		
Turbocharger			TV7701 (TEL)		TEL
Air compressor			ZEXEL		--
Others			--		

Engine model			BSA6D170A-1	
Applicable machine			BDG500	BDG550
Number of cylinder - Bore x Stroke		mm	6 - 170 x 170	
Total piston displacement		cc	23,150	
Firing order			1 - 5 - 3 - 6 - 2 - 4	
Dimensions	Overall length	mm	2002	
	Overall width	mm	1048	
	Overall height (Excluding exhaust pipe)	mm	2015	
Performance	Flywheel horsepower	kW	426 @ 1500	468 @ 1500
		Bhp/rpm	580 @ 1500	637 @ 1500
	High idling speed	rpm	1560 Max.	1560 Max.
	Low idling	rpm	975 ~ 1025	975 ~ 1025
	Min. fuel consumption ratio	g/kWh	214	212
Dry weight		kg	2650	
Fuel pump			Bosch type	
Governor			Mechanical, centrifugal all-speed type	
Lubricating oil amount (refill capacity)		ℓ	67 (50)	
Coolant amount		ℓ	83	
Aternator			24V, 30A	
Starting motor			24V, 9kW	
Battery			12V, 200Ah x 2	
Turbocharger			KTR 150	
Other			-	

GENERAL ASSEMBLY DRAWING

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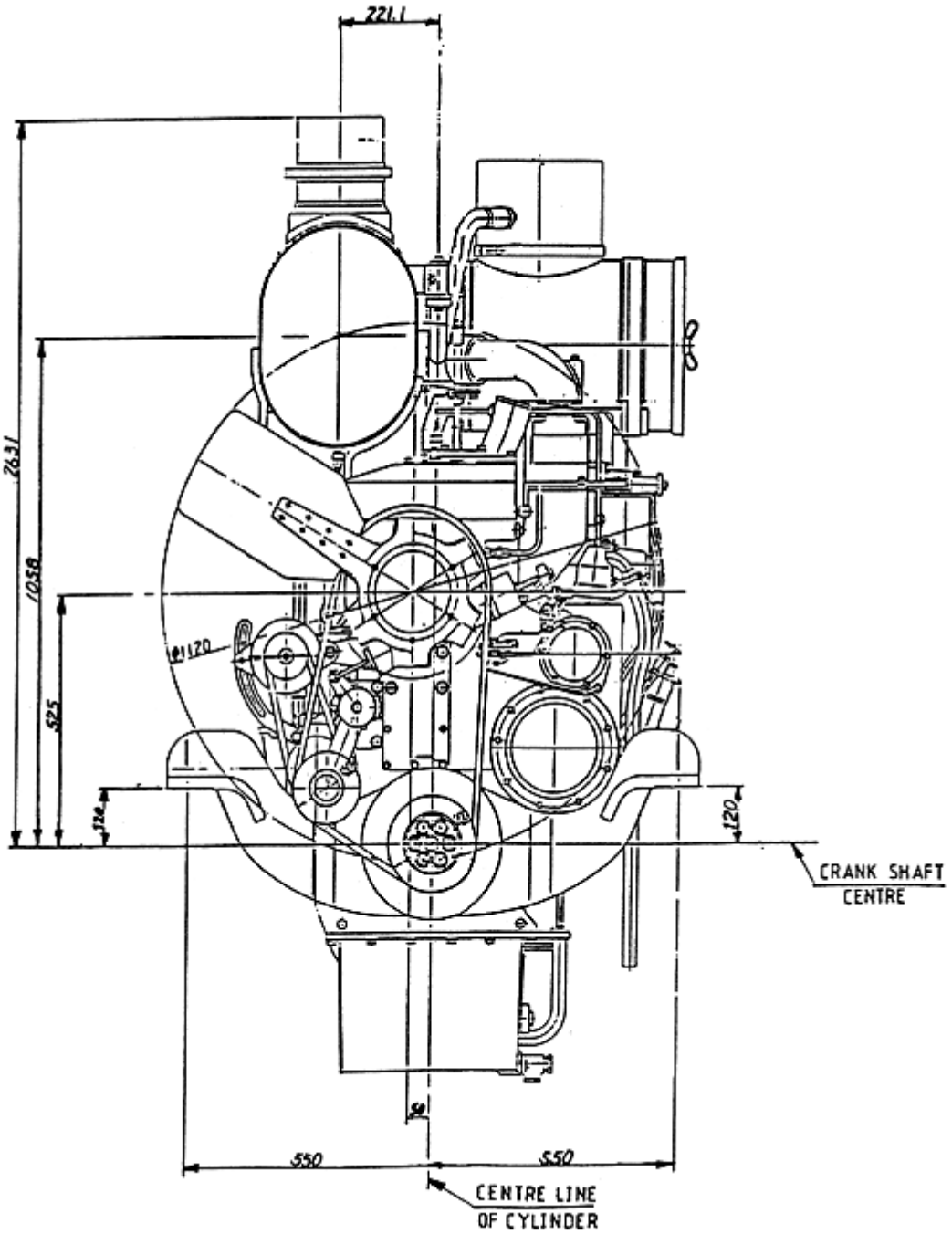
865.2
CRANK SHAFT
CENTRE
REAR FACE OF
FLYWHEEL HOUSING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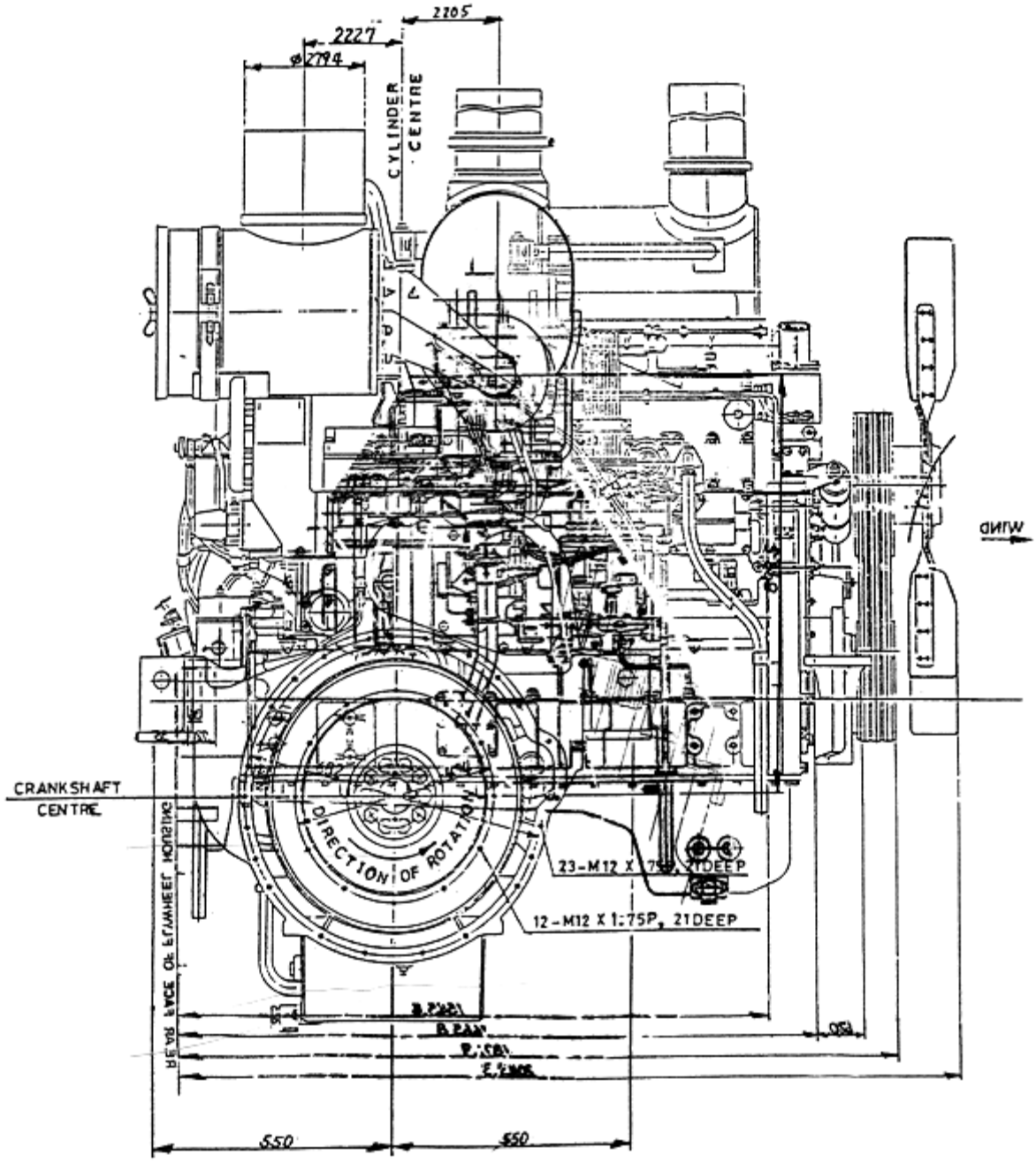
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CYLINDER CENTRE
CRANKSHAFT CENTRE
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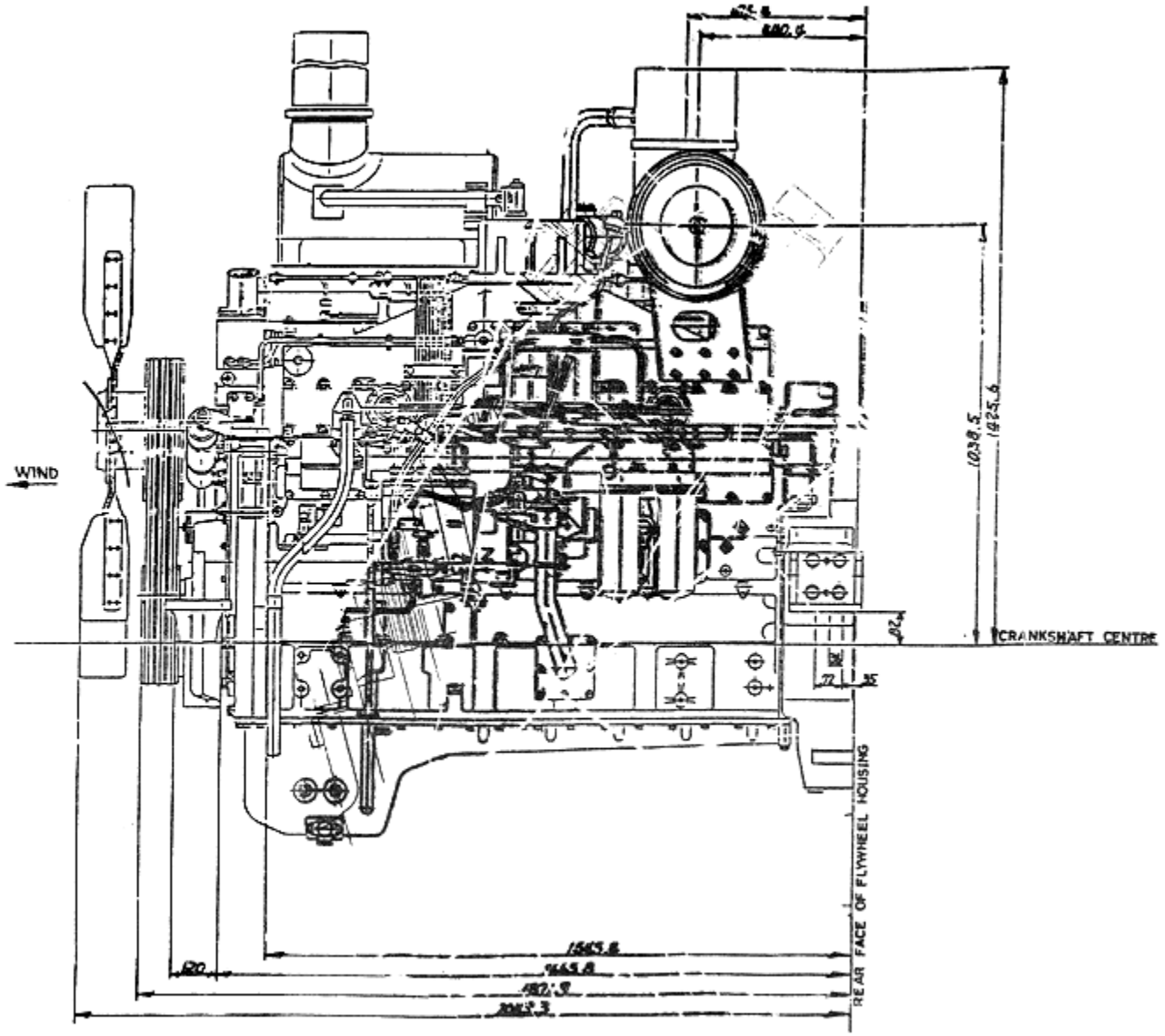
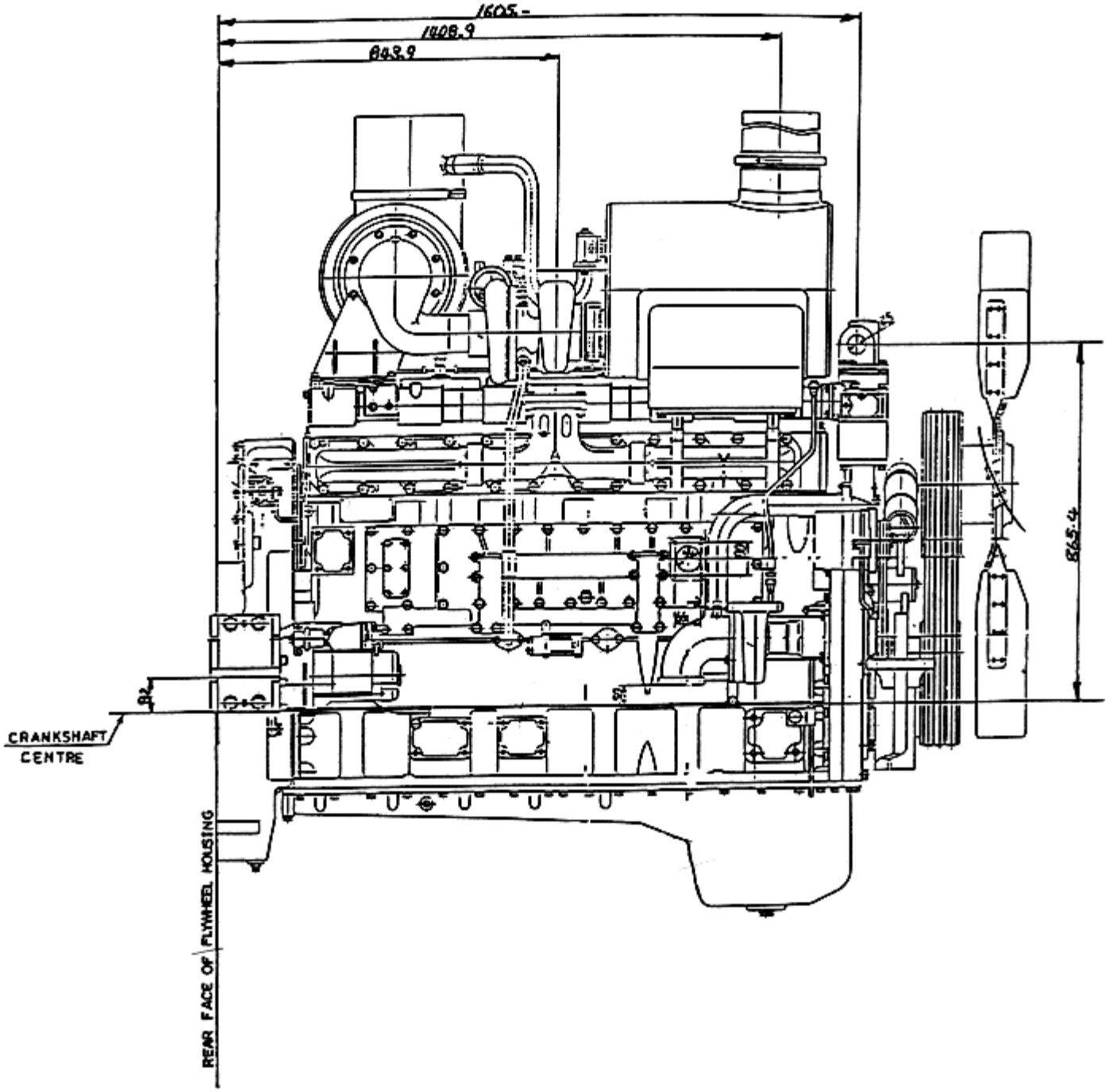
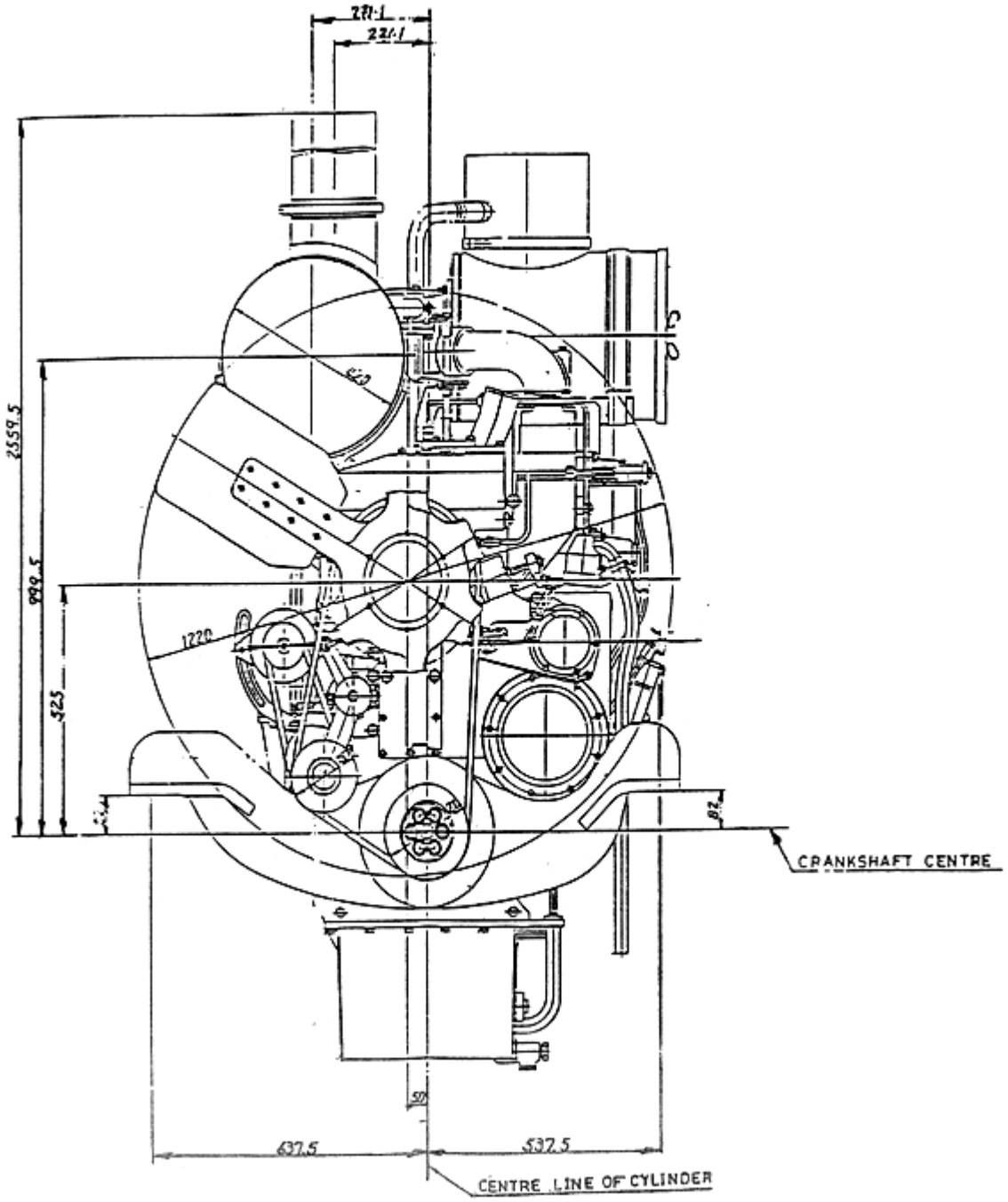
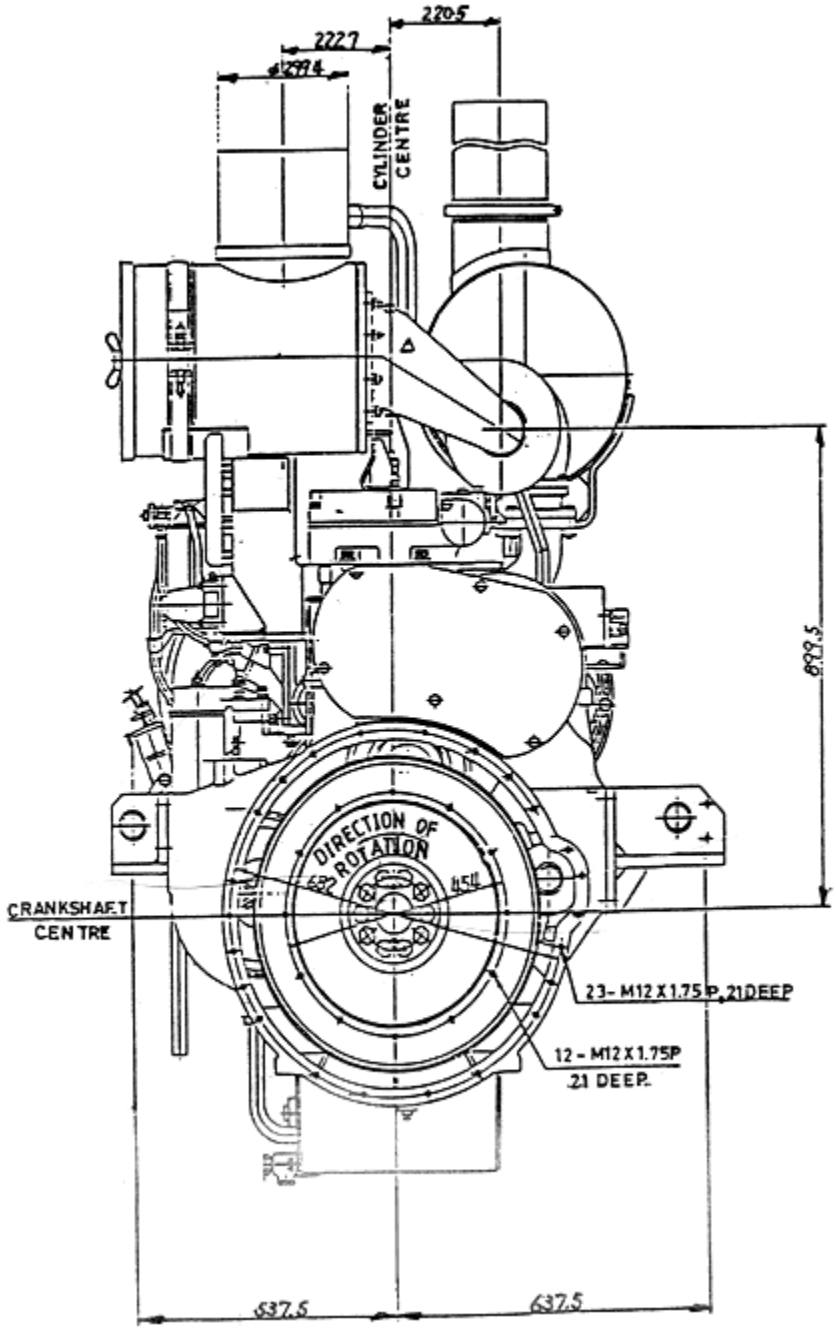
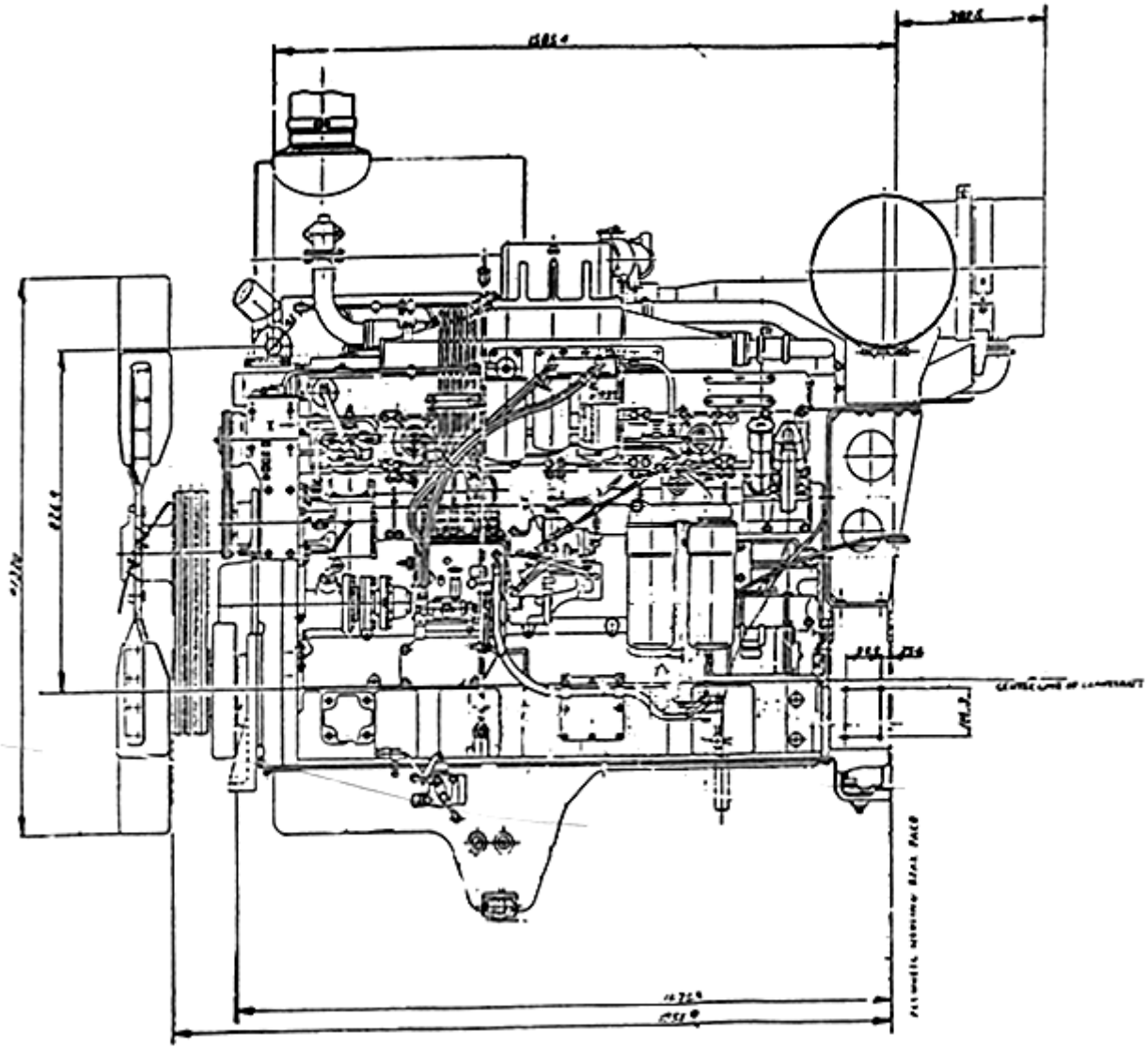
12-M12 X 1.75P, 21DEEP
550
550

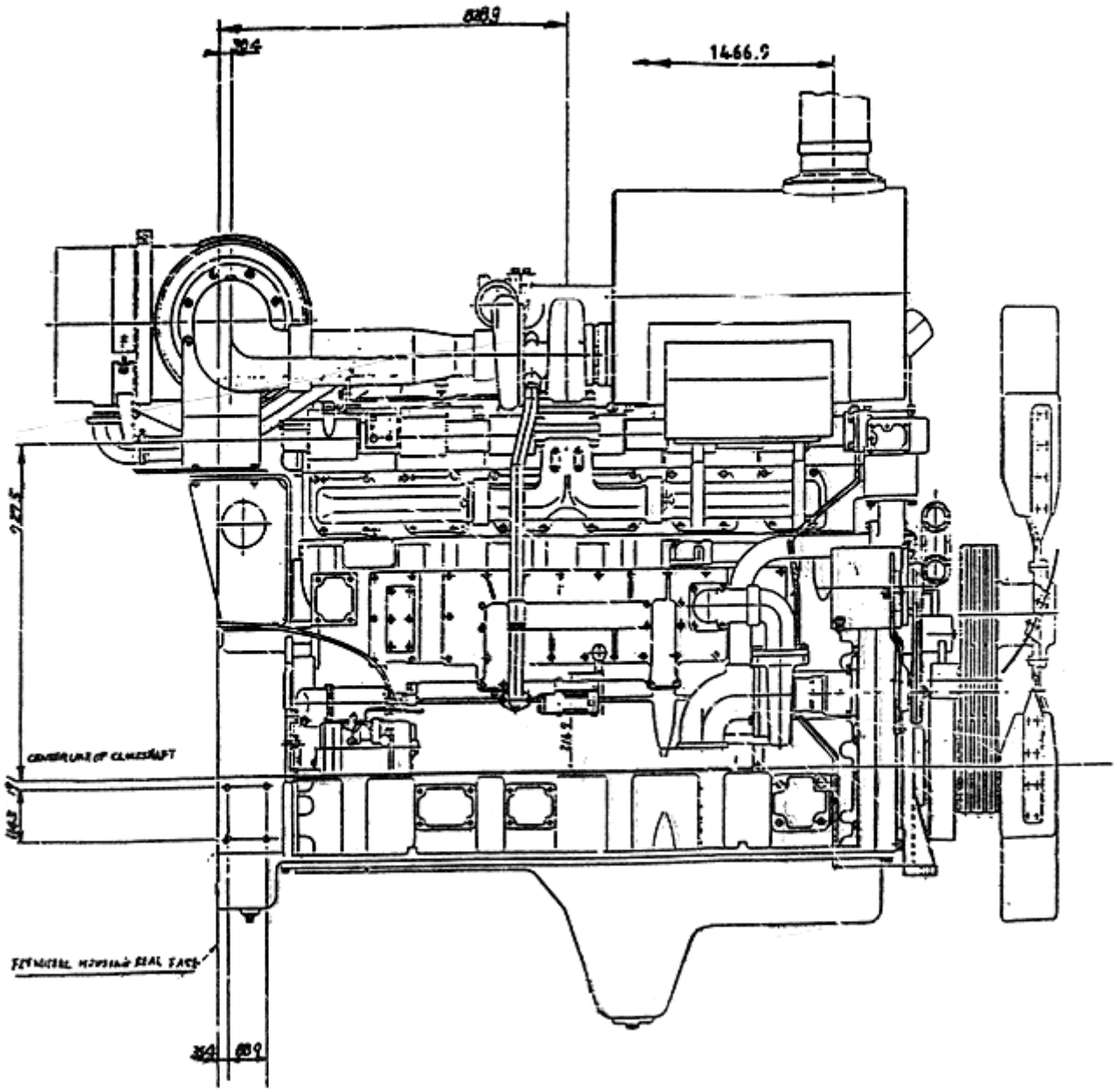

WIND
CRANKSHAFT CENTRE
REAR FACE OF FLYWHEEL HOUSING

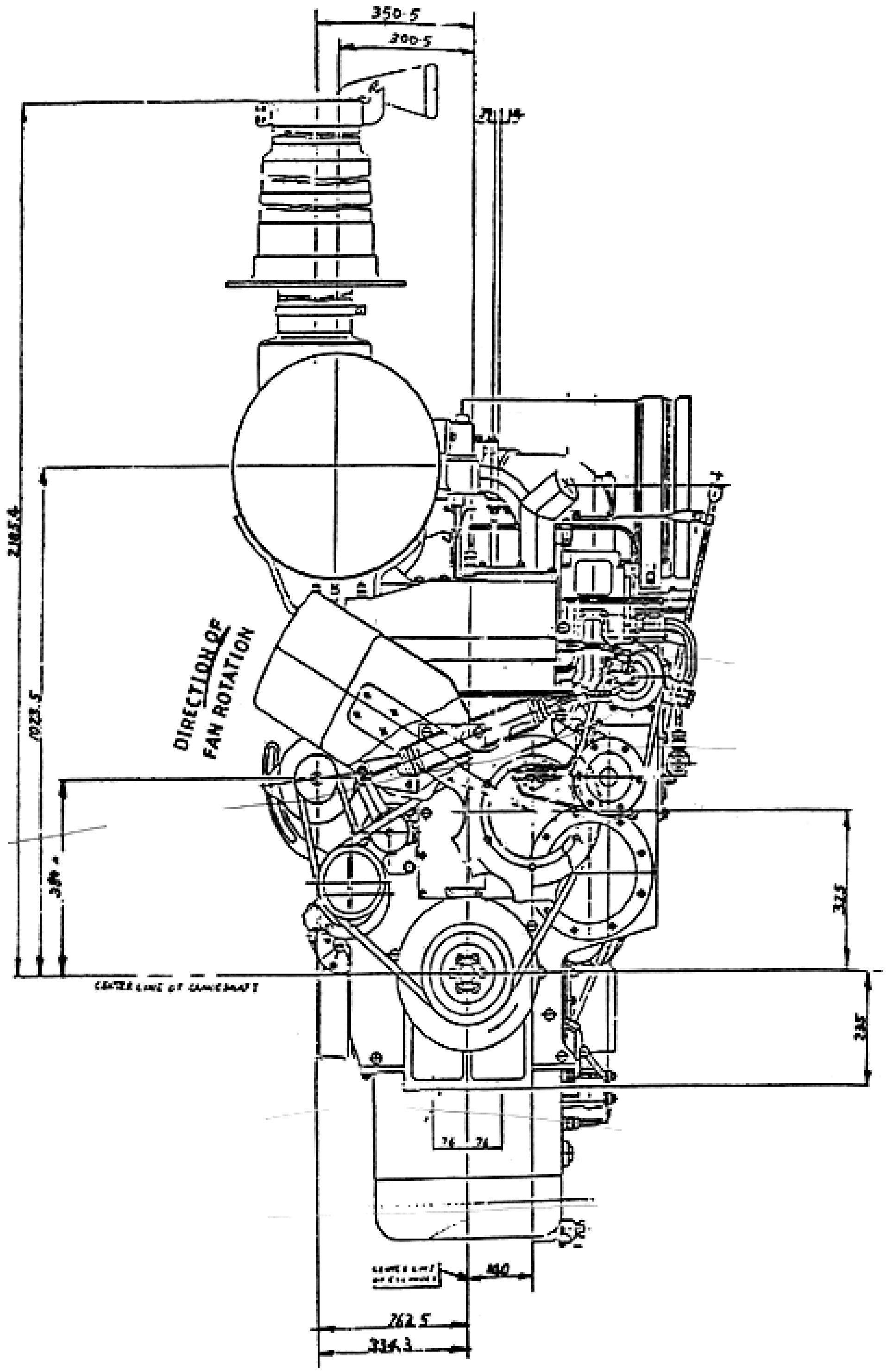

1605
1608.9
848.9
865.4
CRANKSHAFT CENTRE
REAR FACE OF FLYWHEEL HOUSING

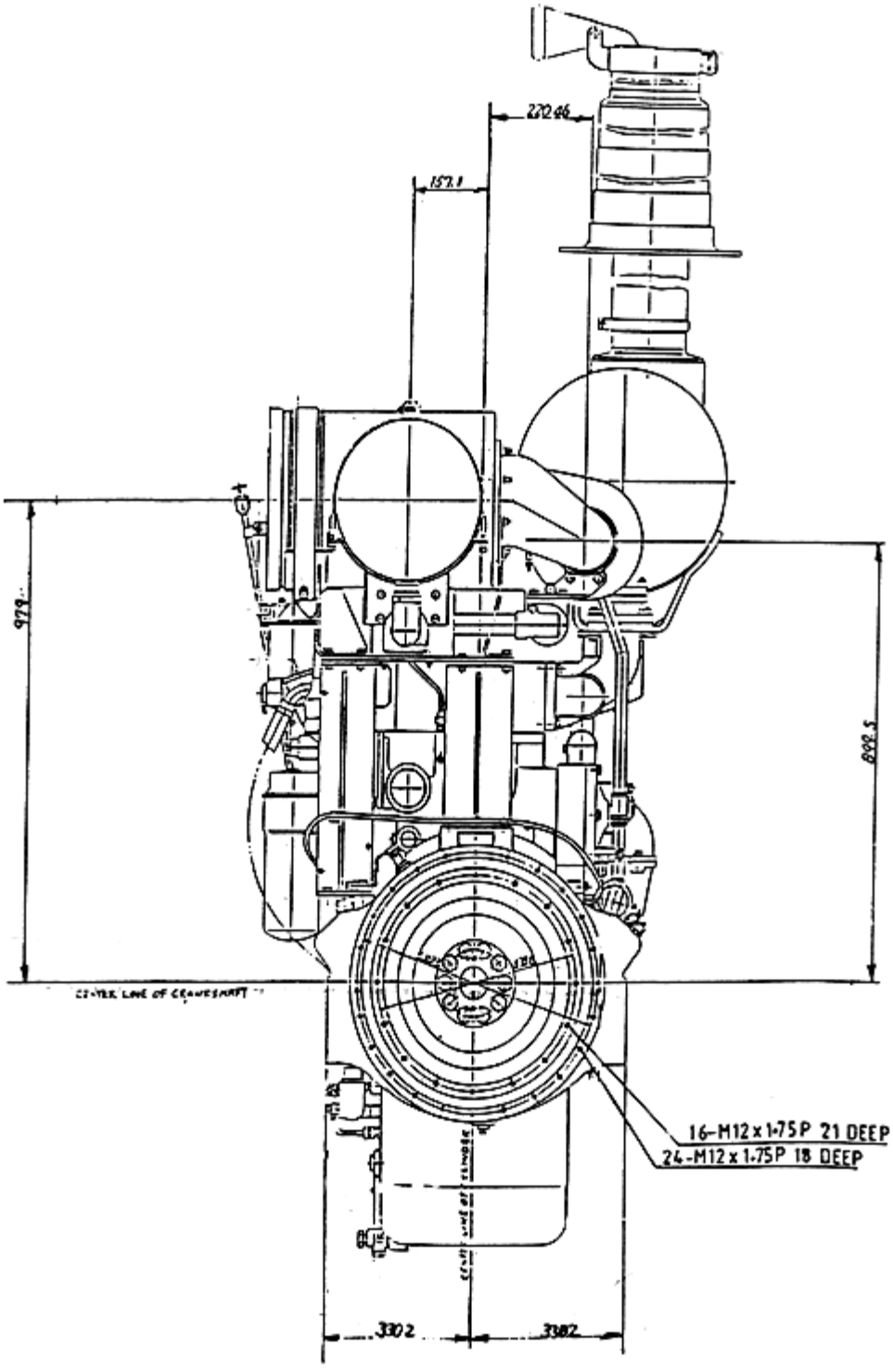

2559.5
999.5
525
1220
637.5
537.5
CRANKSHAFT CENTRE
CENTRE LINE OF CYLINDER


220.5
222.7
ø299.4
CYLINDER CENTRE
ø939.5
DIRECTION OF ROTATION
45°
45°
CRANKSHAFT CENTRE
23- M12 X 1.75 P, 21 DEEP
12 - M12 X 1.75P 21 DEEP.
637.5
637.5




1466.9


350.5
300.5
2185.4
1023.5
DIRECTION OF
FAN ROTATION
325
235
262.5
334.3
160


220.66
157.1
929
CENTER LINE OF CRANKSHAFT
16-M12 x 1.75P 21 DEEP
24-M12 x 1.75P 18 DEEP
330.2
330.2

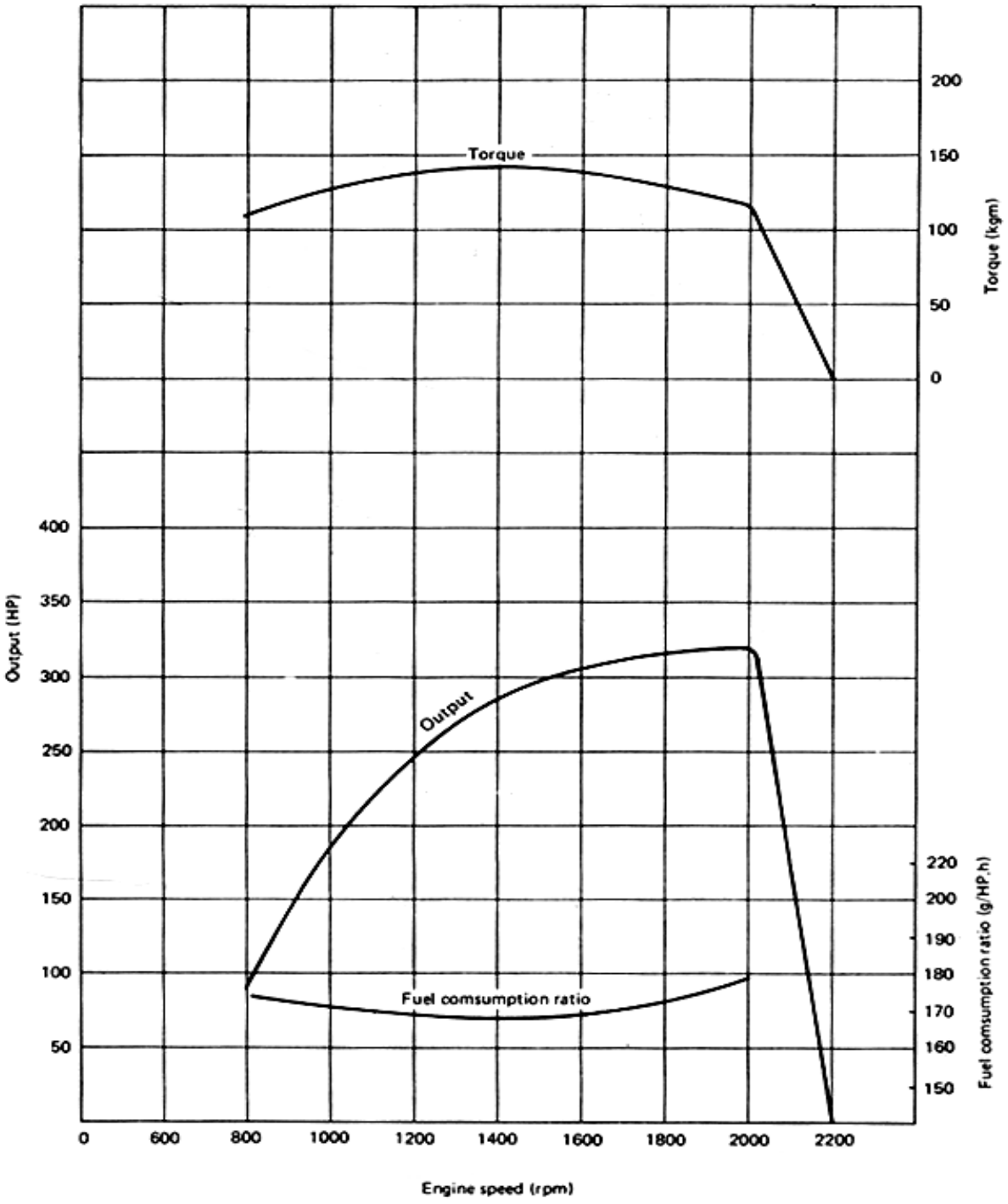
WEIGHT TABLE

No.	ITEM	COMPONENT	BS6D170-1	BSA6D170-1
1	Turbocharger	KTR 110 / KKK	22	-
2	Cylinder head assembly	Cylinder head, vlaue and Valve spring	37	37
3	Cylinder block assembly	Cylinder block, Main bearing cap Cylinder liner	675	675
4	Gear case cover		48	48
5	Timing gear case		30	30
6	Oil pan		45	45
7	Flywheel assembly	Flywheel , Ring gear	83.6	-
8	Flywheel housing		163	-
9	Crankshaft assembly	Crankshaft, Crank gear	270	270
10	Camshaft assembly	Camshaft, cam gear and thrust plate	31	31
11	Piston and connecting rod assembly	Piston, piston ring, piston pin and connecting rod	21	21
12	Oil pump		21	21
13	Fuel injection pump		31	30
14	Water pump		20	20
15	Alternator		9.5	10
16	Starting motor		20	18
17	Air compressor		-	-
18	After cooler		-	43.5

ENGINE PERFORMANCE CURVE

BS6D170-1 (for BD155A-1)

Flywheel horsepower: 320 HP/2,000 rpm
Maximum torque: 144 kgm/1,400 rpm
Minimum fuel consumption ratio: 168 g/HP.h

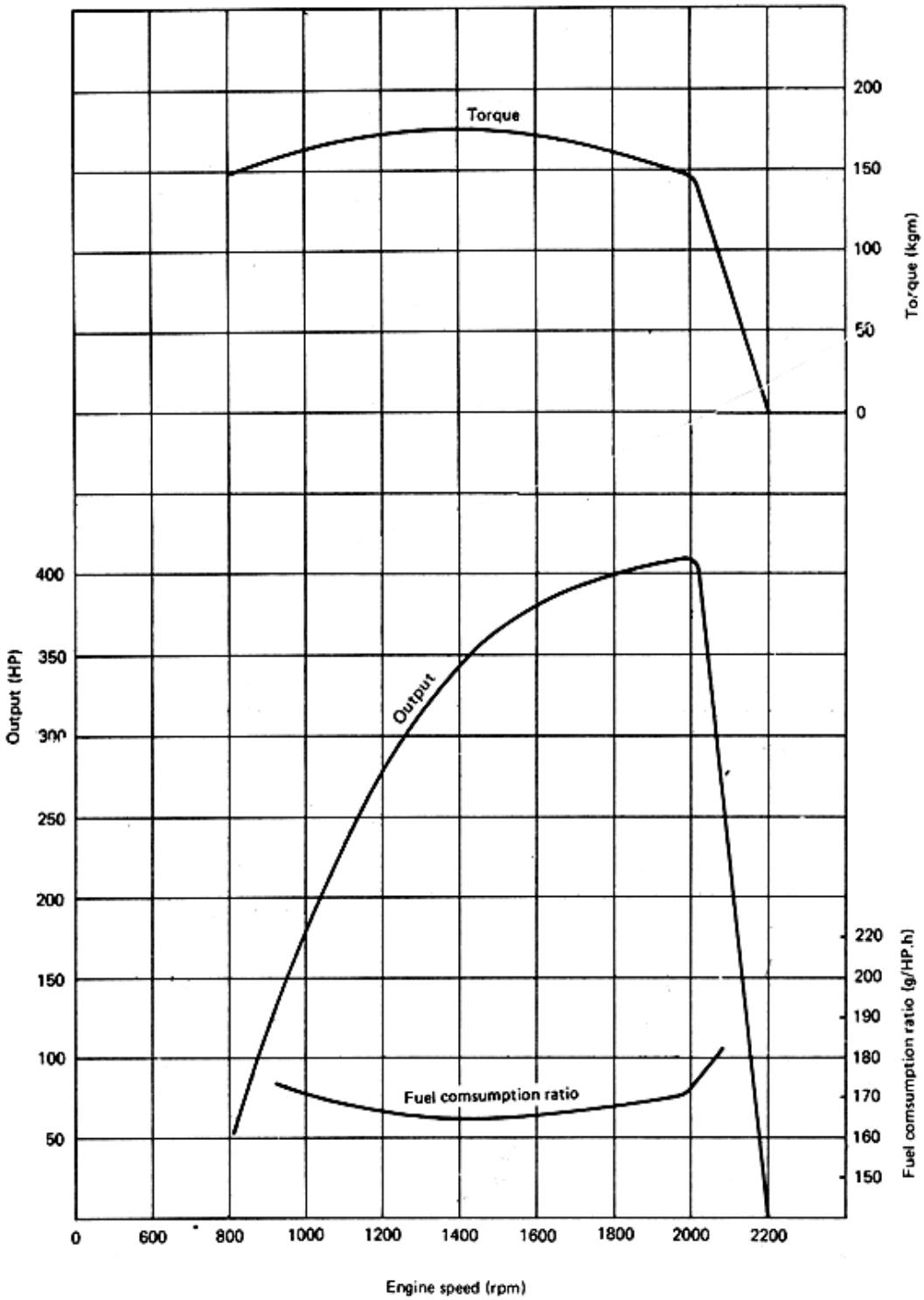


(BS6D170-1) (for BD355A-3)

Flywheel horsepower: 410 HP/2,000 rpm

Maximum torque: 176 kgm/1,400 rpm

Minimum fuel consumption ratio: 164 g/HP.h

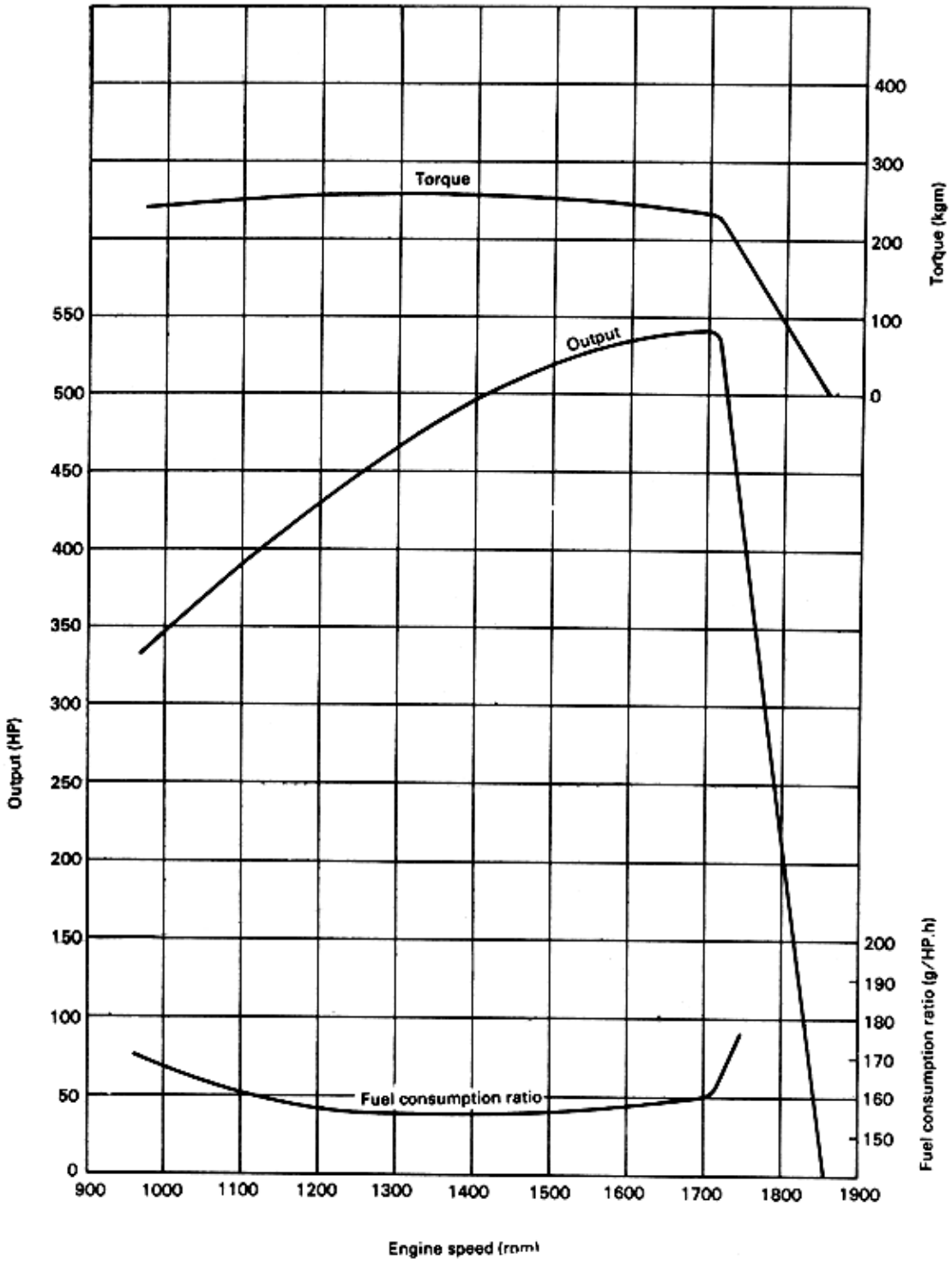


BSA6D170-B-1 BE1000-1

Flywheel horsepower: 542 HP/1,700 rpm

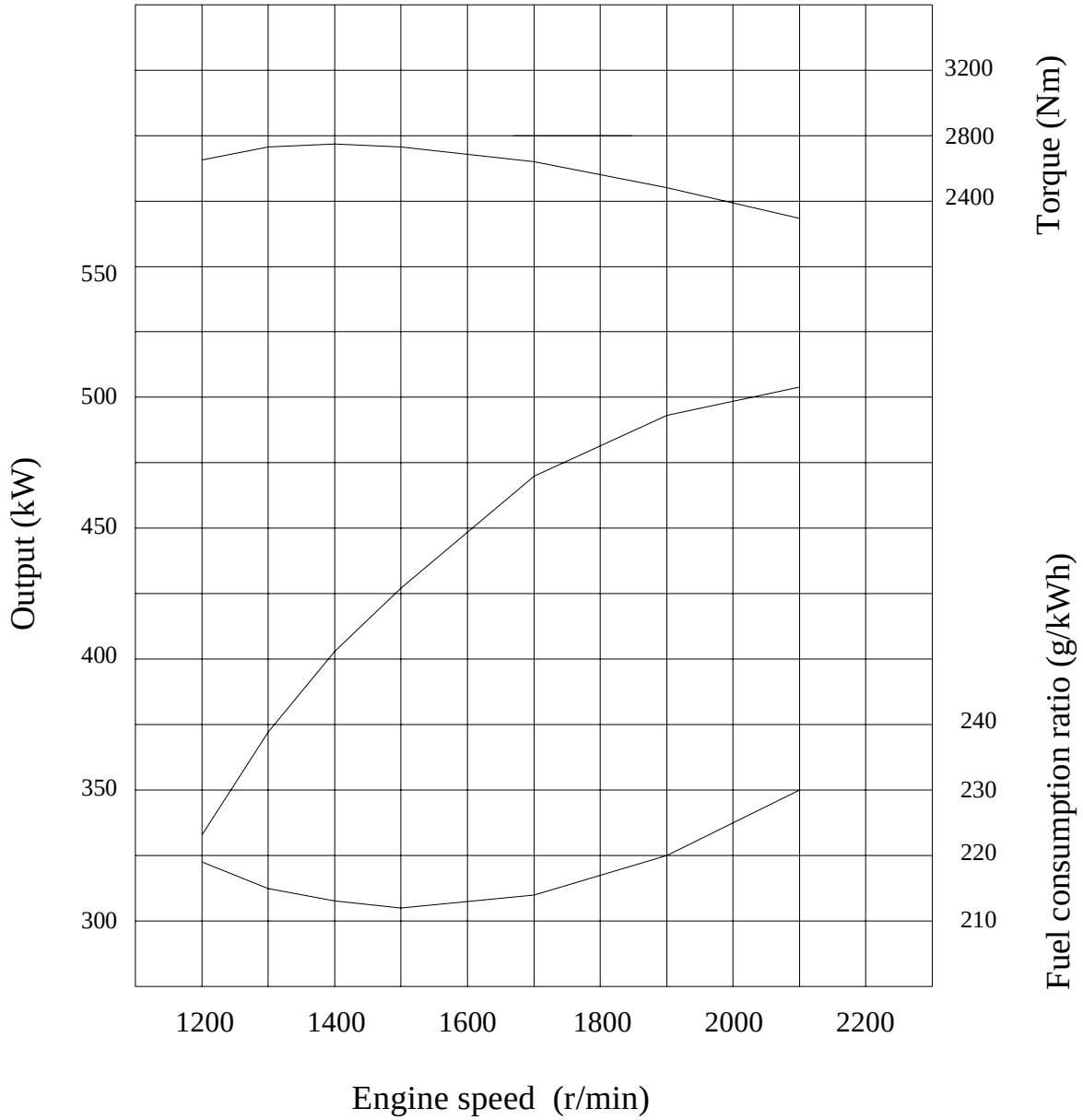
Maximum torque: 260 kgm/1,300 rpm

Minimum fuel consumption ratio: 155 g/HP.h



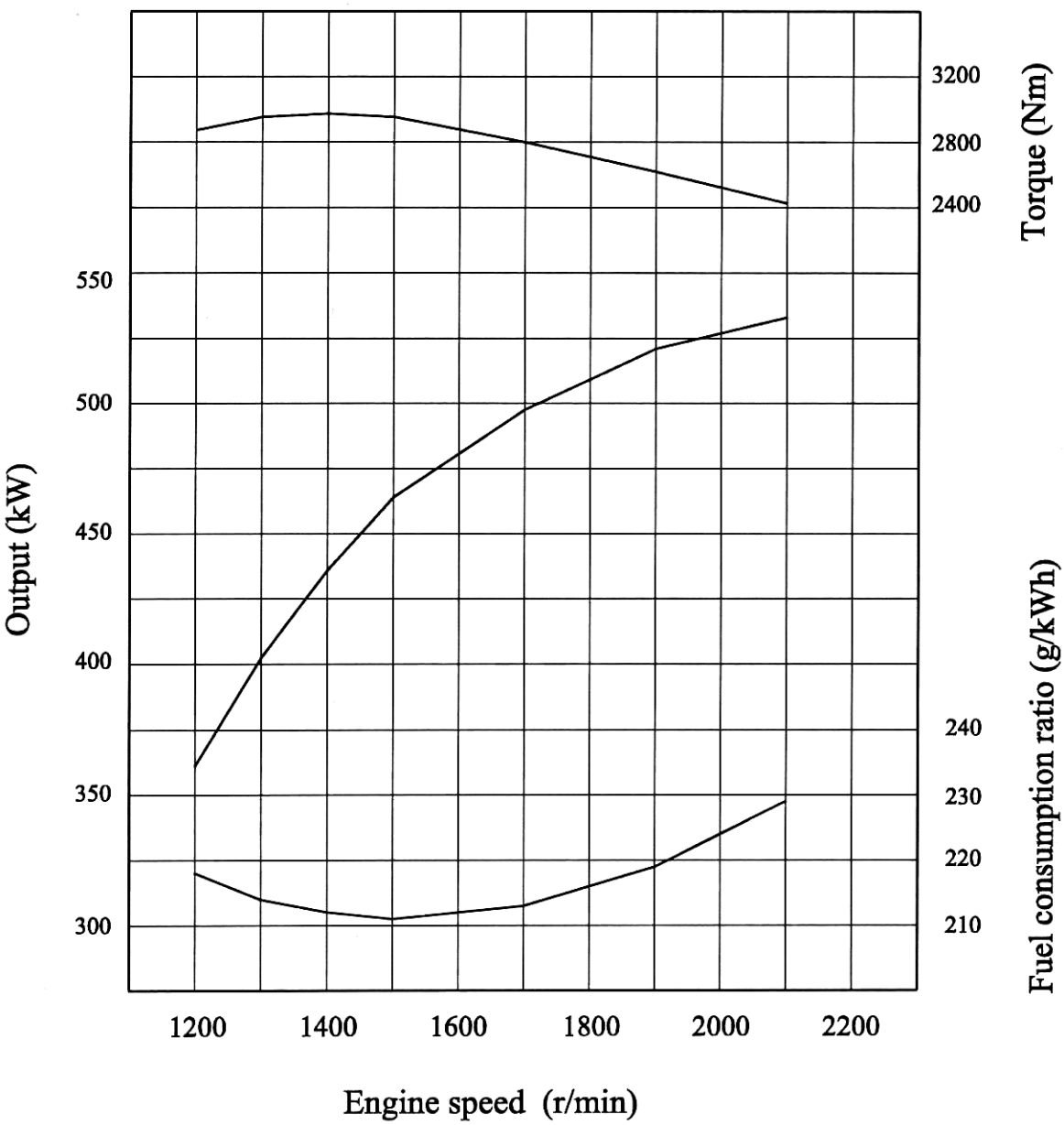
BSA6D170A-1 For BH60

Flywheel horsepower : 504 kW @ 2100 rpm
Max. torque : 2750 Nm @ 1400 rpm
Min. fuel consumption ratio : 212 g/ (kW-hr.)



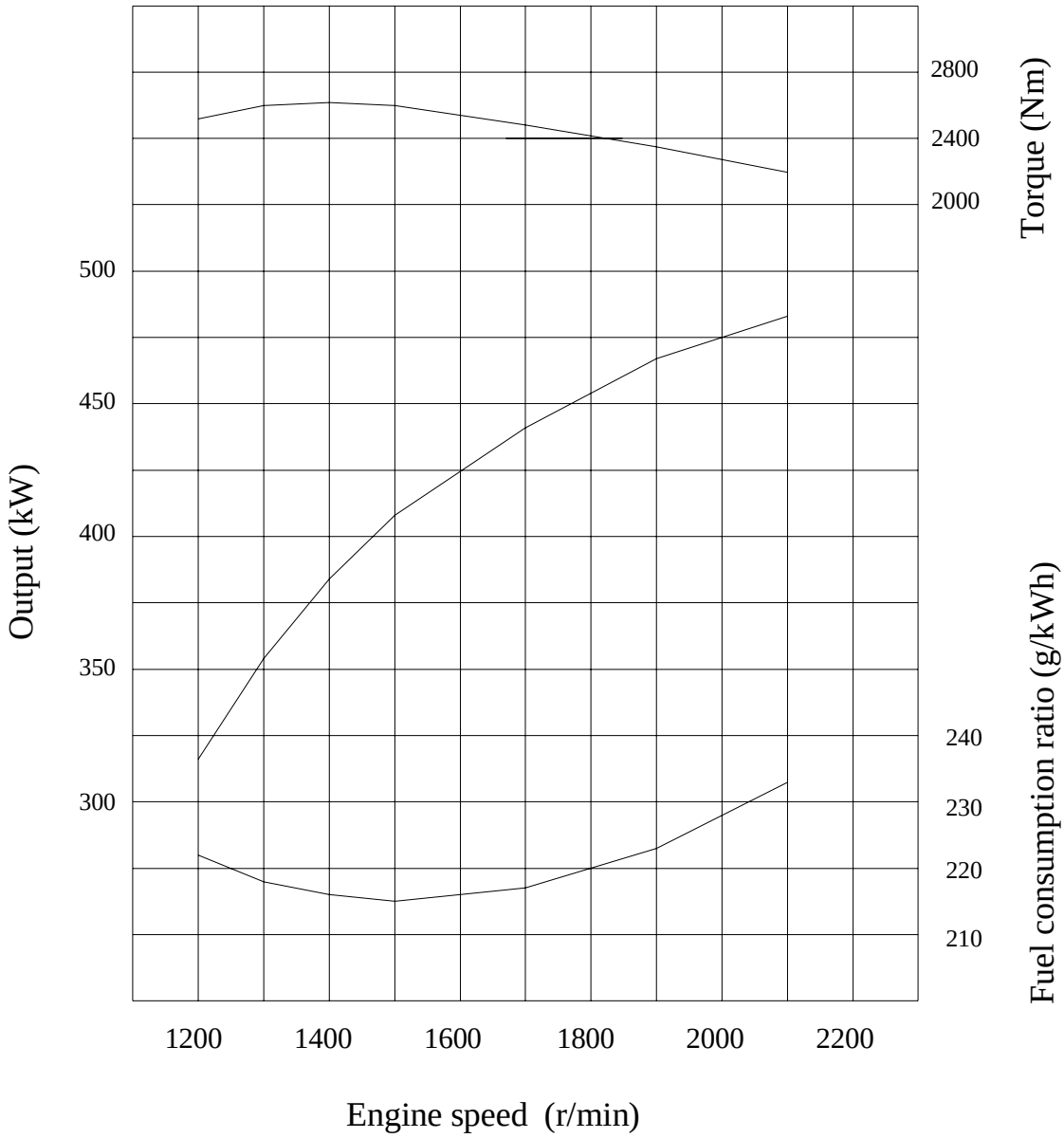
BSA6D170A-1 For BH70

Flywheel horsepower	:	533 kW @ 2100 rpm
Max. torque	:	2975 Nm @ 1400 rpm
Min. fuel consumption ratio	:	211 g/ (kW-hr.)



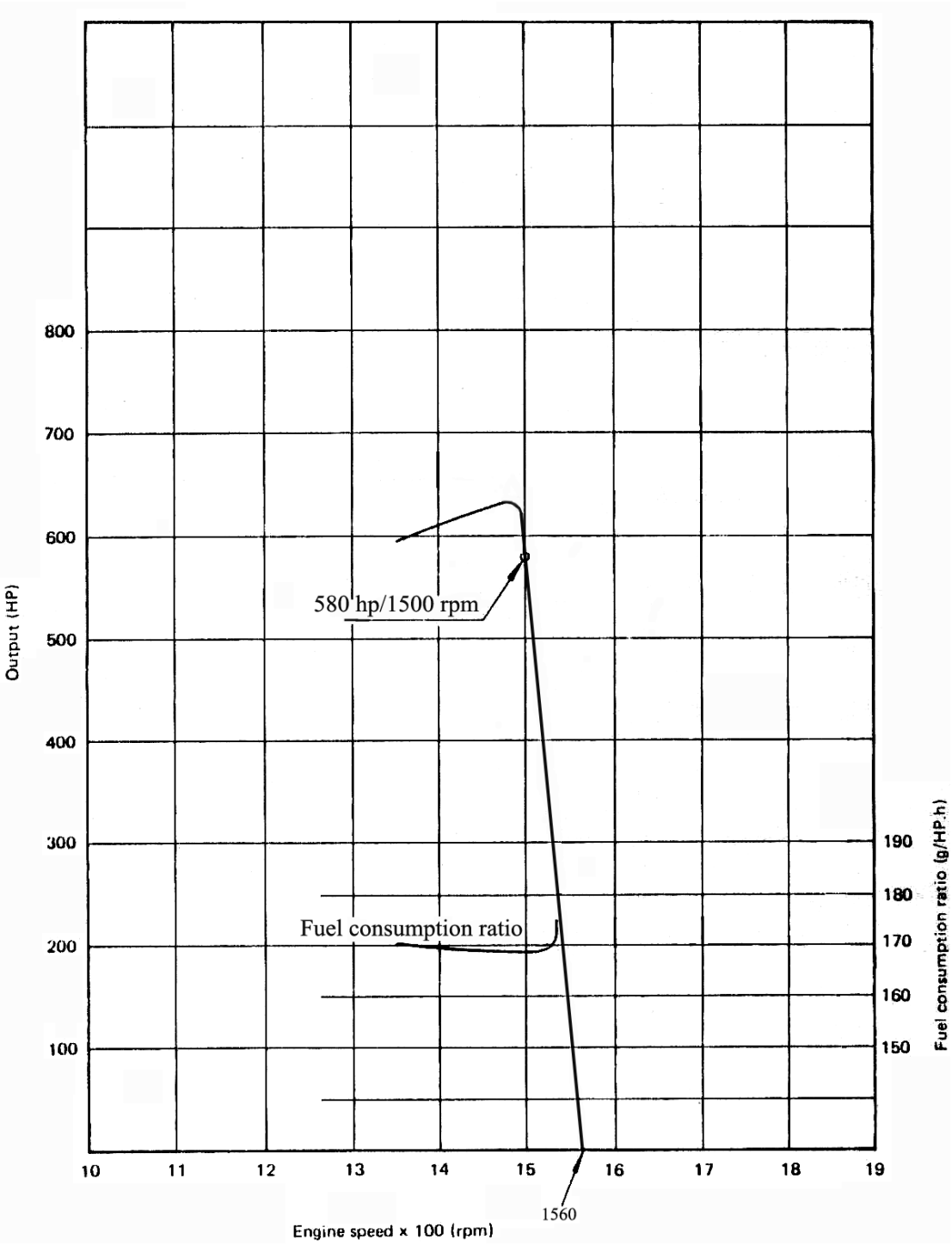
BSA6D170A-1 For 210M

Flywheel horsepower : 483 kW @ 2100 rpm
Max. torque : 2618 Nm @ 1400 rpm
Min. fuel consumption ratio : 215 g/ (kW-hr.)



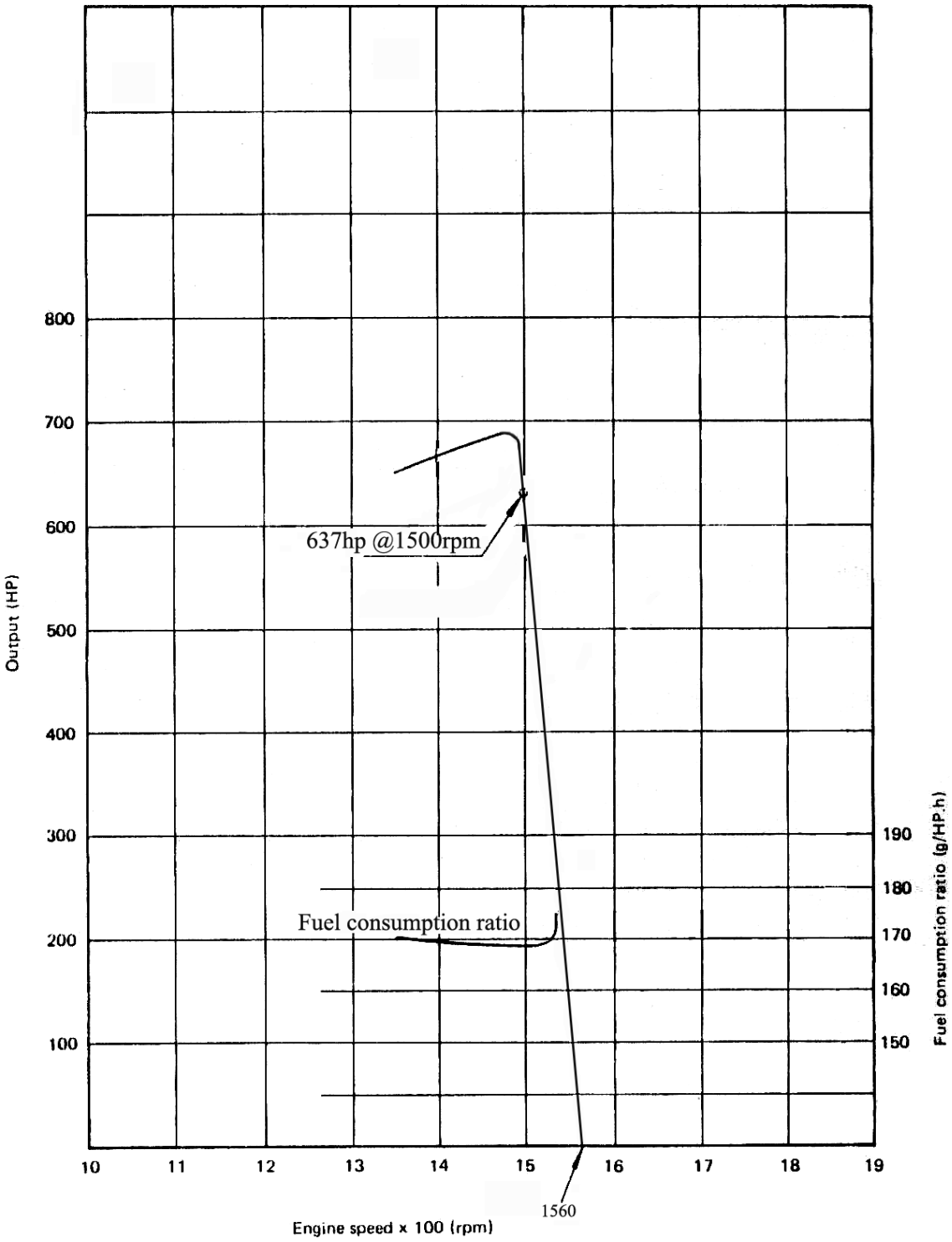
BSA6D170A-1 For BDG500

Flywheel horsepower : 580 HP @ 1500 rpm



BSA6D170A-1 For BDG550

Flywheel horsepower : 637 HP @ 1500 rpm

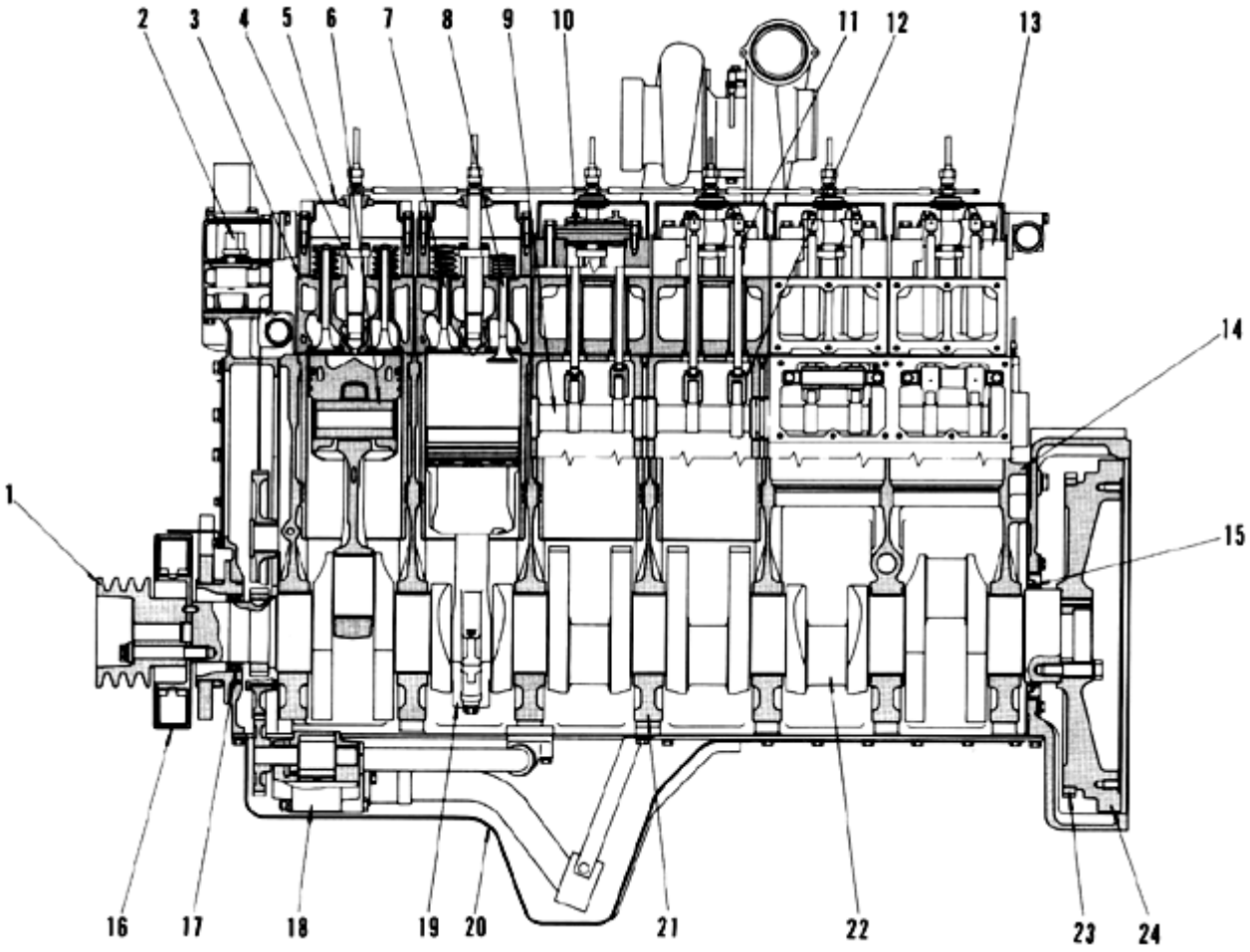


ENGINE

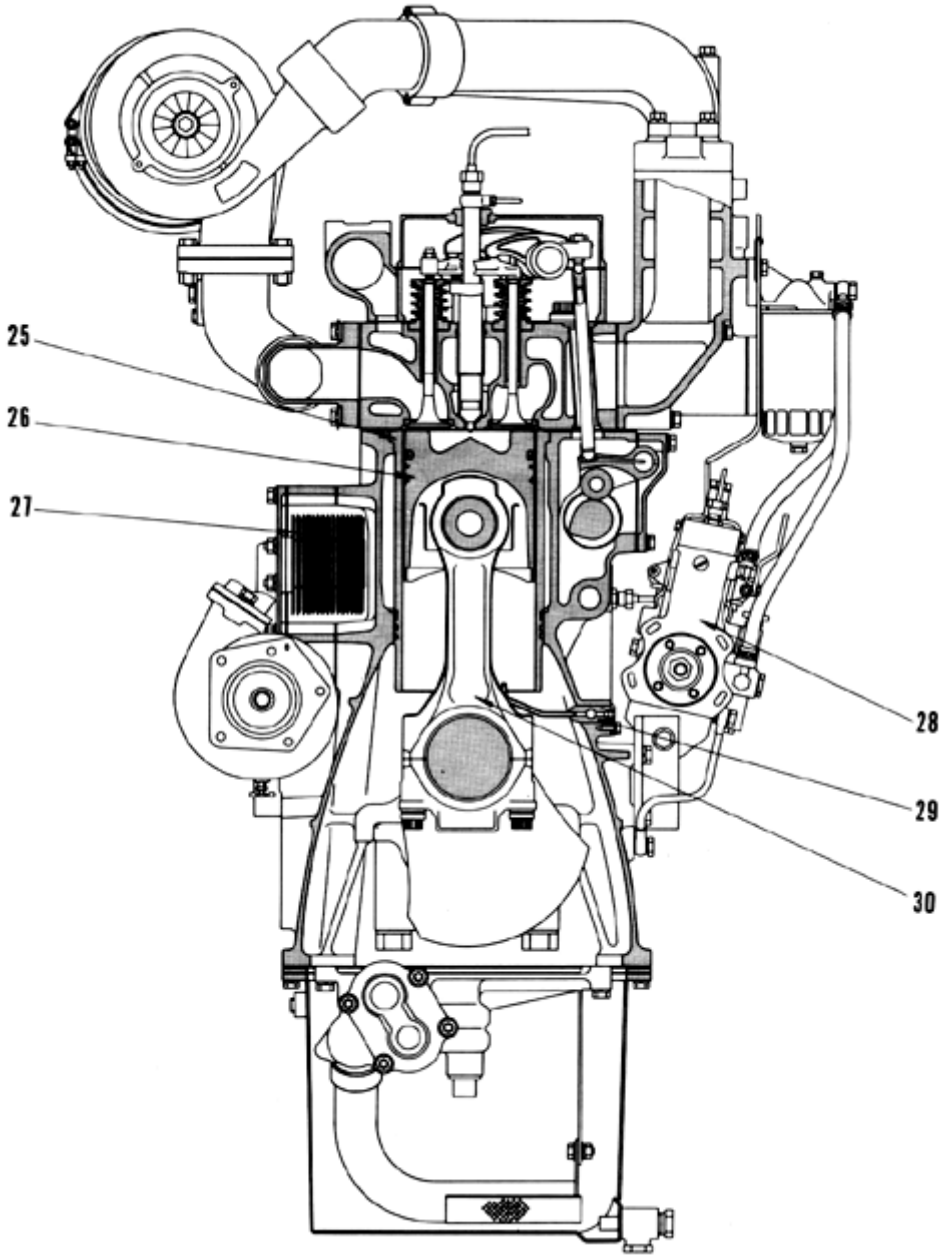
12 STUCTURE AND FUNCTION

GENERAL STRUCTURE

BS6D170-1



1. Crank pulley
2. Thermostat
3. Cylinder head
4. Fuel injection nozzle
5. Rocker arm housing cover
6. Piston pin
7. Intake valve
8. Exhaust valve
9. Camshaft
10. Rocker arm shaft
11. Push rod
12. Tappet
13. Rocker arm housing
14. Cylinder block
15. Rear seal
16. Vibration damper
17. Front seal
18. Oil pump
19. Connecting rod cap
20. Oil pan
21. Main bearing cap
22. Crankshaft
23. Ring gear
24. Flywheel



25. Cylinder liner

26. Piston

27. Oil cooler

28. Fuel injection pump

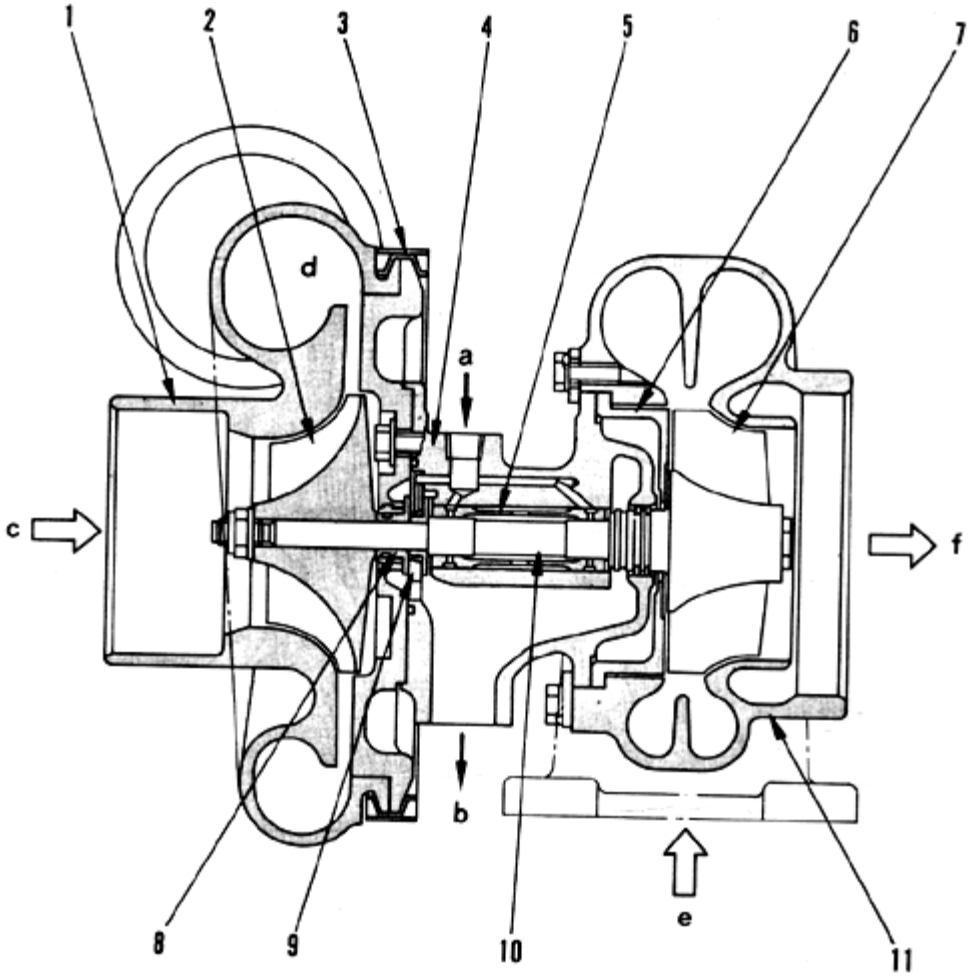
29. Piston cooling nozzle

30. Connecting rod

INTAKE AND EXHAUST SYSTEM

TURBOCHARGER

KTR110



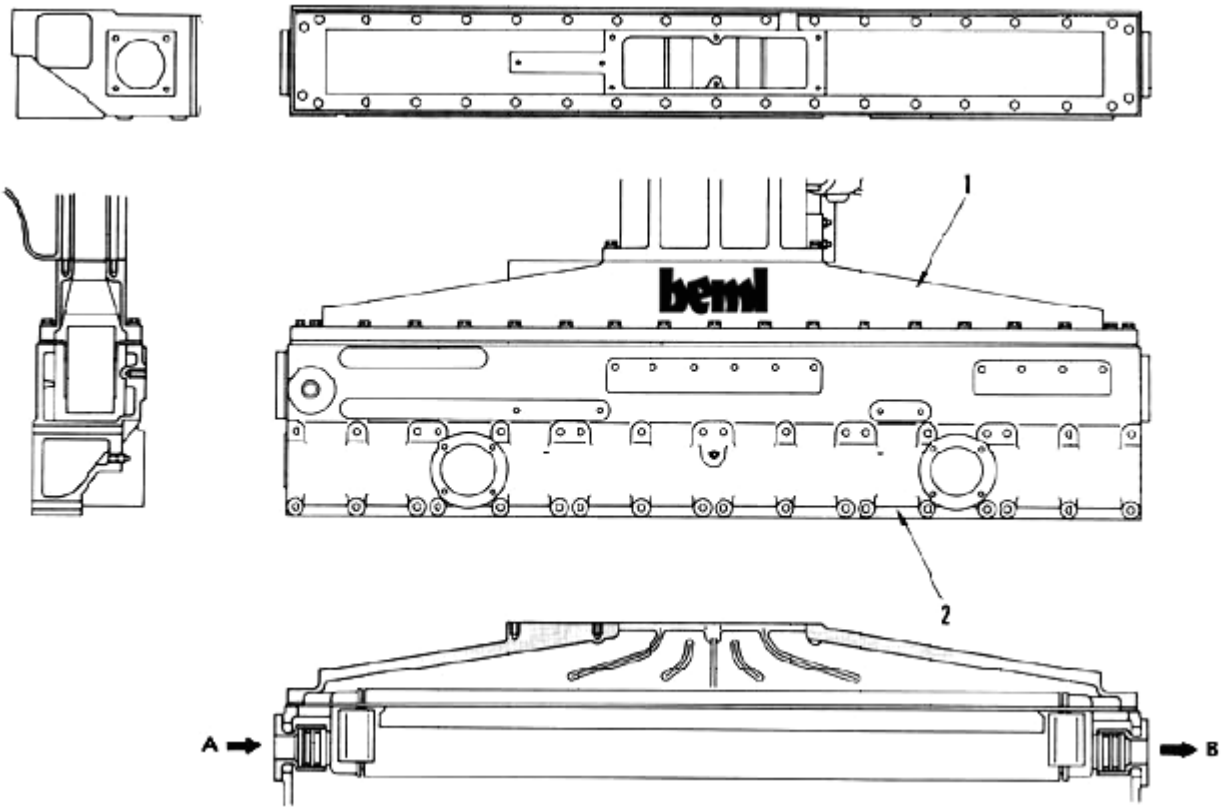
1. Blower housing
2. Blower impeller
3. Clamp
4. Center housing
5. Journal, bearing
6. Shield
7. Turbine impeller
8. Flinger
9. Thrust bearing
10. Turbin shaft
11. Turbine housing

a. Oil inlet (from oil filter)
b. Oil outlet (to oil pan)
c. Air inlet
d. Air outlet
e. Exhaust inlet
f. Exhaust outlet

TURBOCHARGER

Type	: KTR110
Overall length	: 290 mm
Overall width	: 305 mm
Overall height	: 267 mm
Weight	: 19 kg
Maximum allowable rotation	: 94,000rpm
Maximum charging	: 46 kg/min.
Maximum allowable temperature (inlet)	: 750° C max.
Direction of rotation (view from blower side)	: Right
Lubrication method	: Forced lubrication with engine oil

AFTER - COOLER

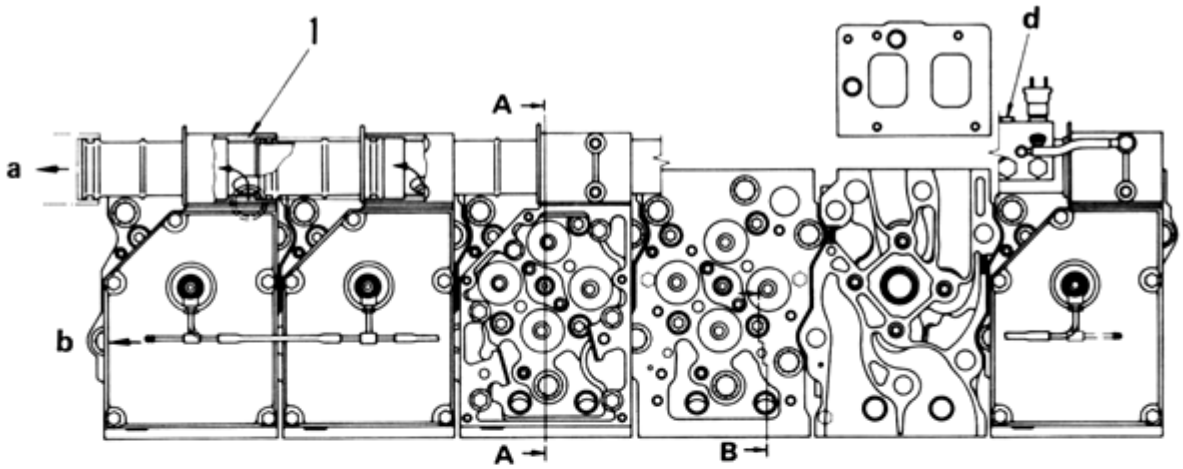


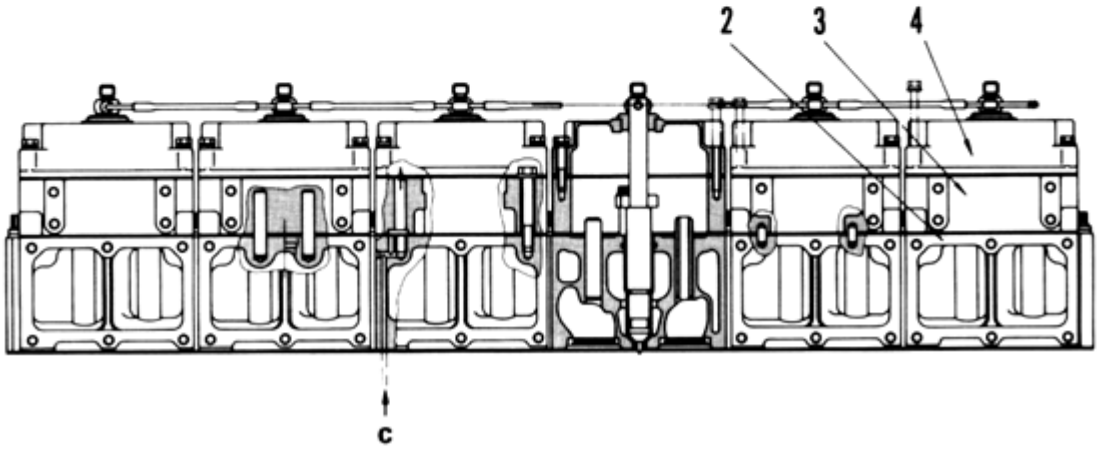
1. Cover
2. After-cooler body

A: From water pump
B: To water manifold

ENGINE BODY

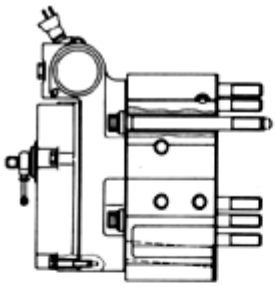
CYLINDER HEAD

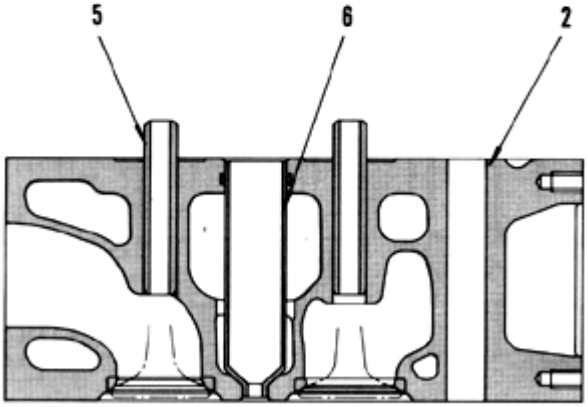




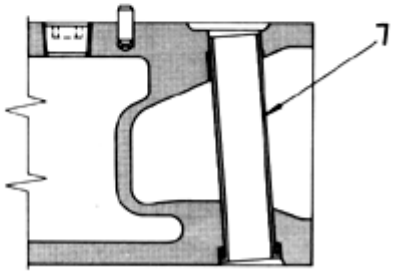
1. Water manifold
2. Cylinder head
3. Rocker arm housing
4. Rocker arm housing cover
5. Valve guide
6. Nozzle holder sleeve
7. Tube

a. Coolant (to radiator)
b. Fuel (return)
c. Oil (from main gallery)
d. Tap for water temperature gauge sensor





Section **A - A**



Section **B - B**

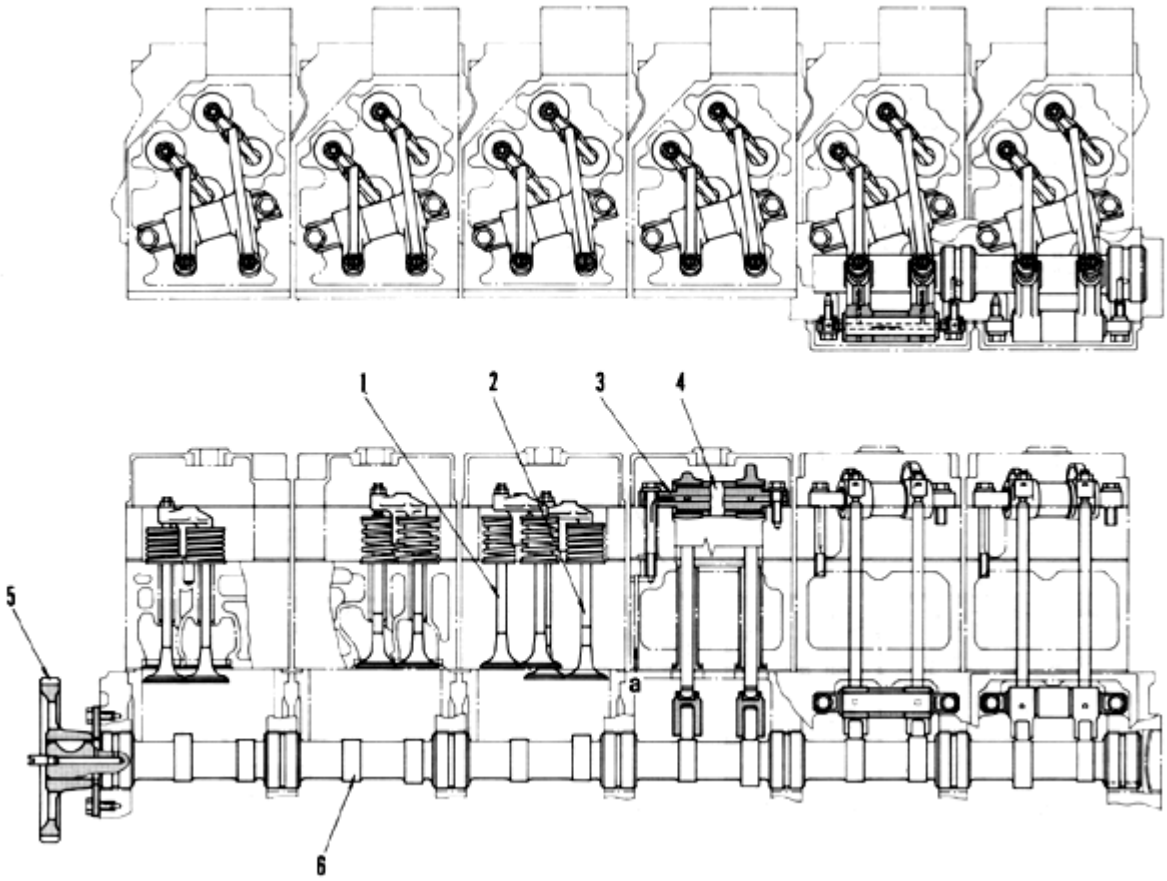
Cylinder head

. Direct-injection type, injection nozzle, 4-valve type
. Separate type (1-head for 1-cylinder)

Valve seat

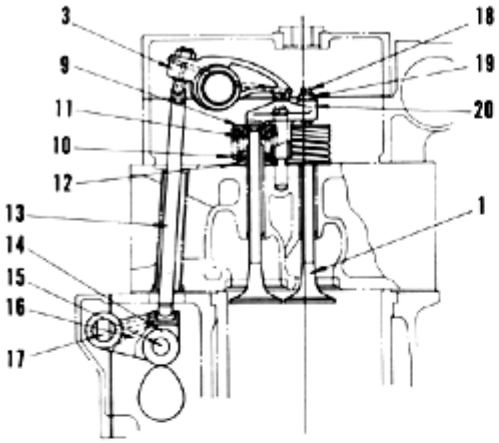
. Press fitted into cylinder head of intake valve and exhaust valves.

VLAVE SYSTEM

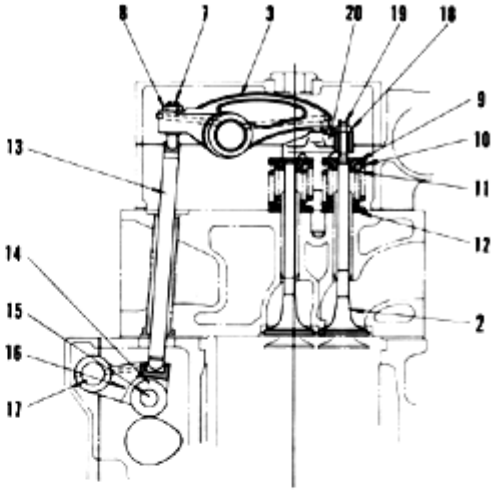


1. Intake valve
2. Exhaust valve
3. Rocker arm
4. Collar
5. Camshaft gear (No. of teeth:48)
6. Camshaft
7. Adjustment screw
8. Lock nut
9. Upper spring seat
10. Valve spring (outer)
11. Valve spring (inner)
12. Lower spring seat
13. Push rod
14. Cam roller
15. Cam follower pin
16. Cam follower
17. Cam follower shaft
18. Adjustment screw
19. Lock nut
20. Cross head

a. Oil (from oil pump)

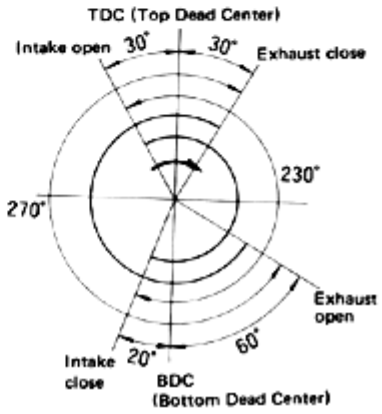


Intake side of No. 1 cylinder



Exhaust side of No. 1cylinder

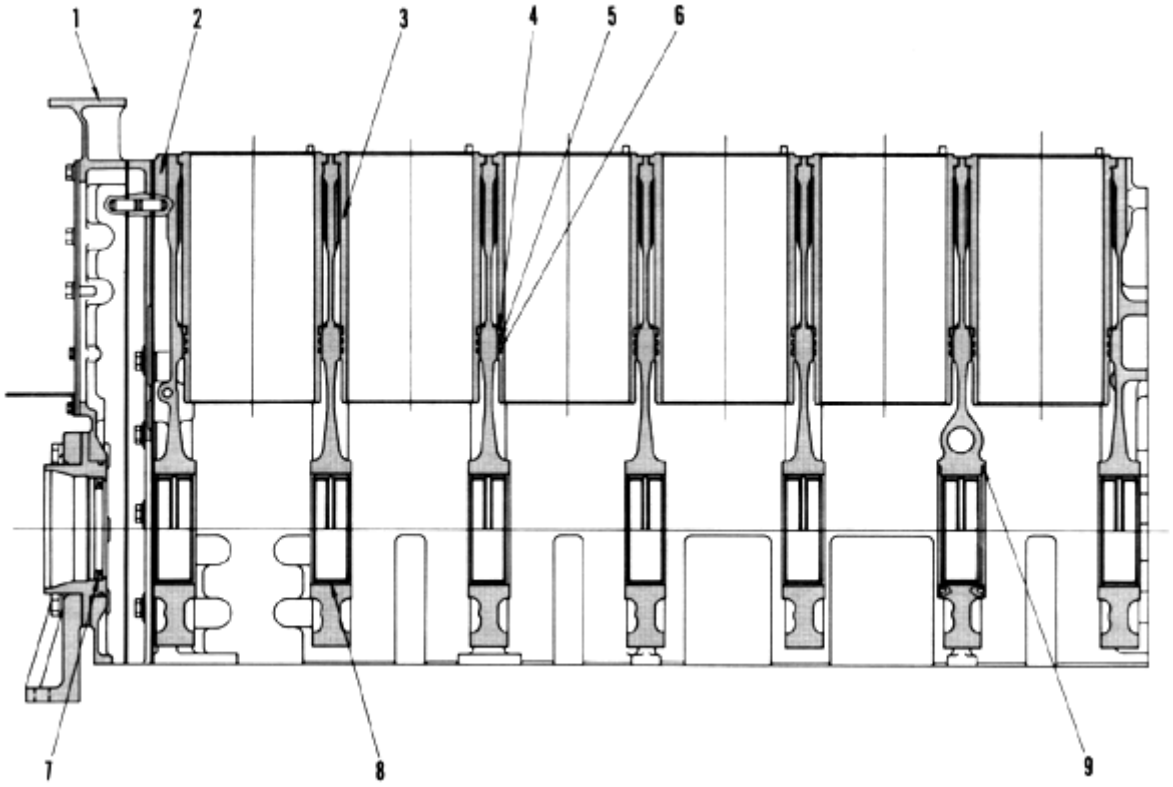
Valve timing



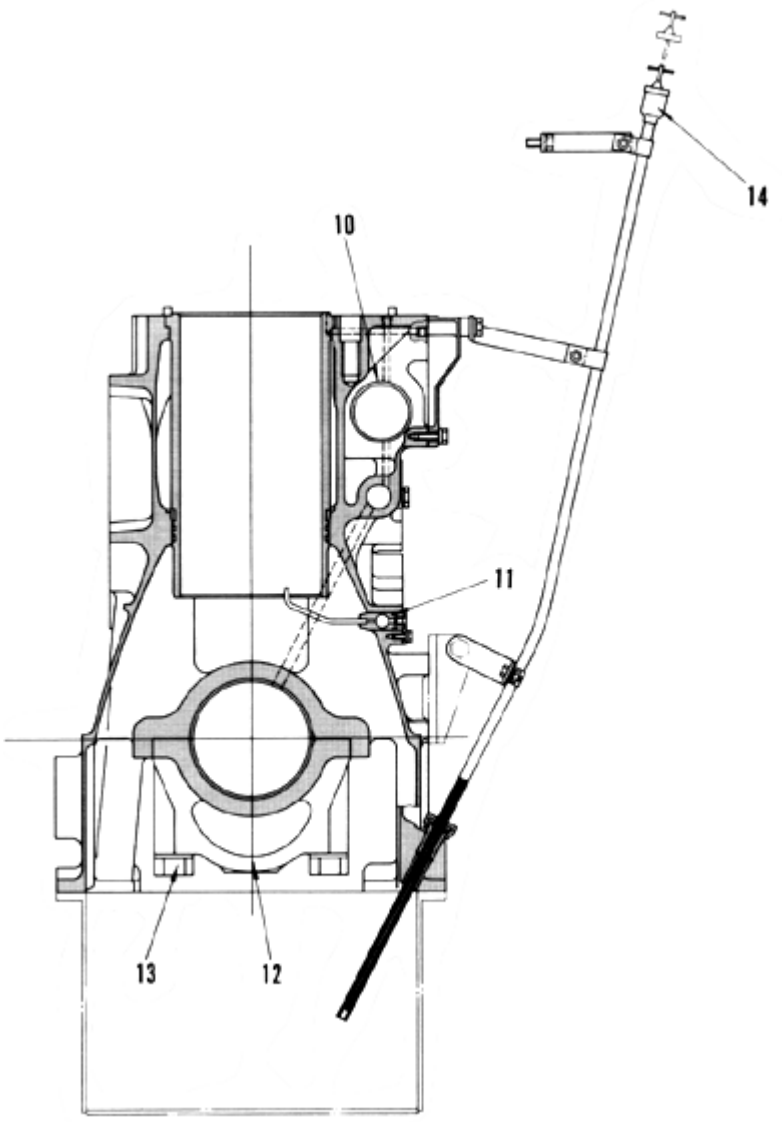
Cam shaft

- Special cast/forged alloy, 7 bearings
- Cam face and journal face: High frequency hardening

CYLINDER BLOCK



1. Front cover
2. Cylinder block
3. Cylinder liner
4. Crevice seal
5. O-ring (nitrile rubber: black)
6. O-ring (silicone rubber: red)
7. Front seal
8. Main bearing
9. Thrust bearing
10. Cam bushing
11. Piston cooling nozzle
12. Main bearing cap
13. Main bearing cap bolt
14. Oil level gauge



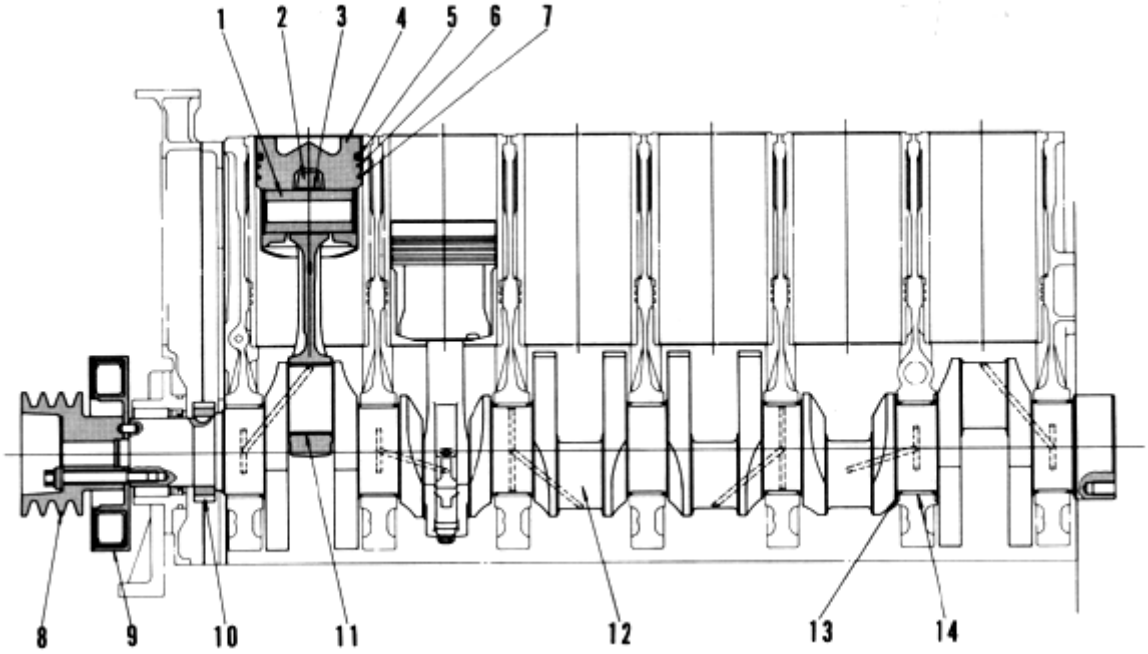
Cylinder block

. Crankshaft: Seven bearings
. Camshaft: Seven bearings

Cylinder liner

. Wet type liner, tufftride treatment on bore surface
. Crevice seal, two O-rings

MAIN CIRCULATION PART

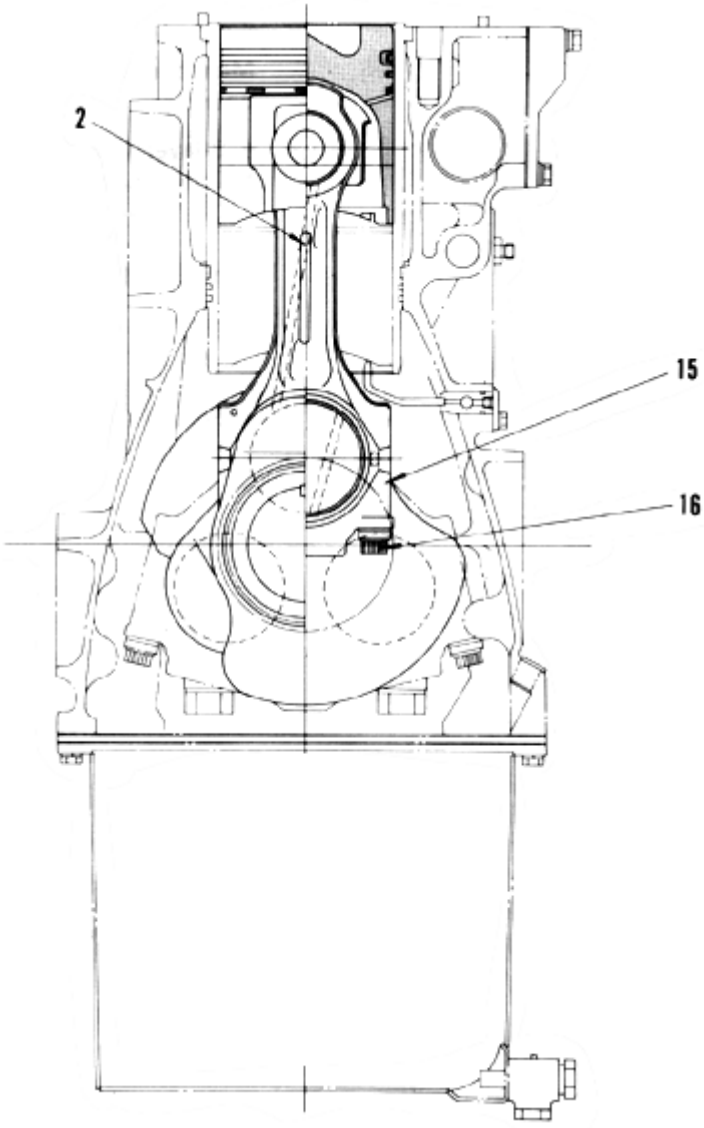


1. Piston pin
2. Connecting rod
3. Connecting rod bushing
4. Piston
5. Top ring
6. 2nd ring
7. Oil ring
8. Crank pulley
   (Outside diameter: 200 mm)
9. Vibration damper
10. Crank gear (No. of teeth: 36)
11. Connecting rod bearing
12. Crankshaft
13. Thrust bearing
14. Main bearing
15. Connecting rod cap
16. Connecting rod bolt

Crankshaft

- Special cast/forged alloy, seven bearings
- Journal face: High frequency hardening

ALUMINUM PISTON TYPE



Main bearing and connecting rod bearing

. 3-layer Kelmet
. Upper main bearing: with oil groove

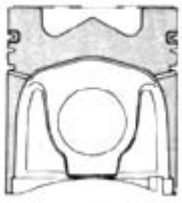
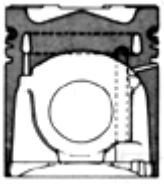
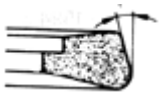
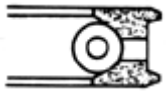
Piston

. Lo-Ex aluminum alloy
. Groove of top ring: Niresist is cast on top ring.
. Thermal flow solid type (BS6D170-1)
. Thermal flow shaker type
(BSA6D170-1)
(BSA6D170-B-1)
. Forced cooling with piston cooling

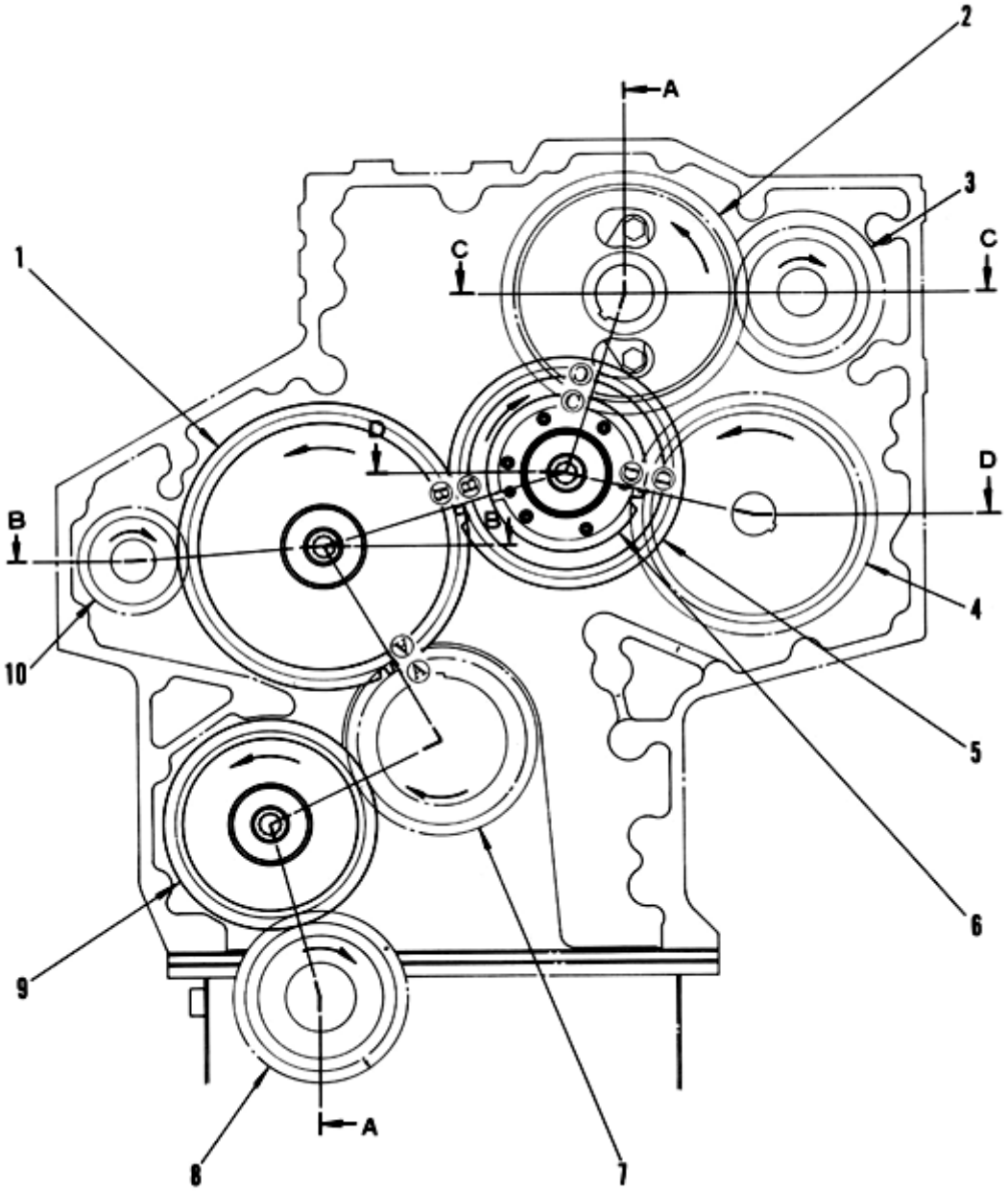
Connecting rod

. Forged alloy steel

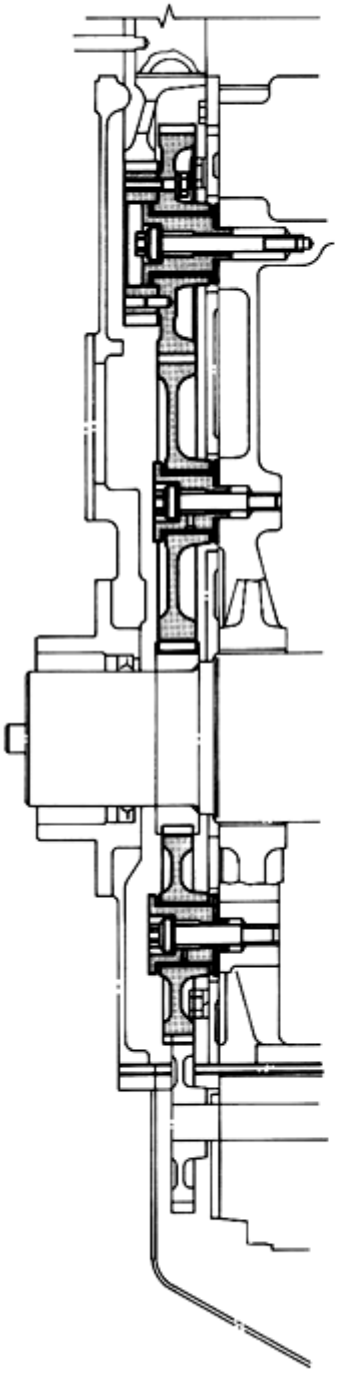
Piston **Piston ring**

Solid type	Shaker type Engine	Top ring	2nd ring	Oil ring
	 BS6D170-1 BSA6D170-B-1	2-face keystone barrel face Hard chrome plating 	2-face keystone inner cut taper face Hard chrome plating 	Bevel cutter with coil expander Hard chrome plating 

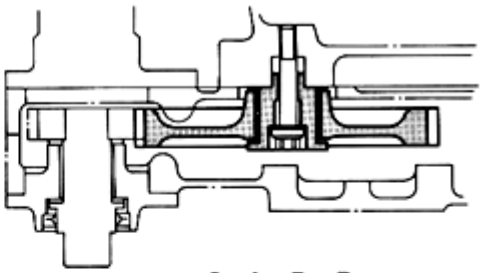
TIMING GEAR



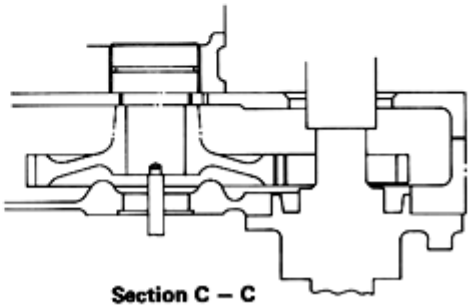
1. Idler gear (No. of teeth: 57)
2. Cam gear (No. of teeth: 48)
3. Compressor driving gear (No. of teeth: 24)
4. Injection pump driving gear (No. of teeth: 48)
5. Idler gear (No. of teeth: 45)
6. Idler gear (No. of teeth: 30)
7. Crankshaft gear (No. of teeth: 36)
8. Oil pump driving gear (No. of teeth: 33)
9. Idler gear (No. of teeth: 41)
10. Water pump driving gear (No. of teeth: 20)



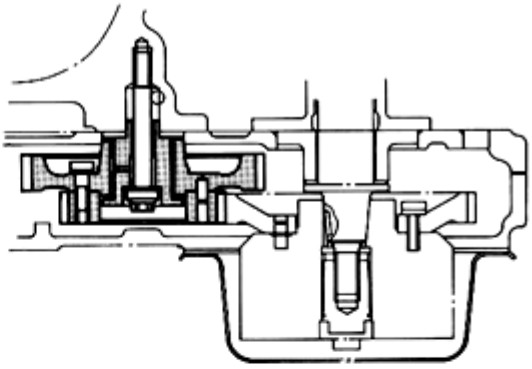
Section A – A



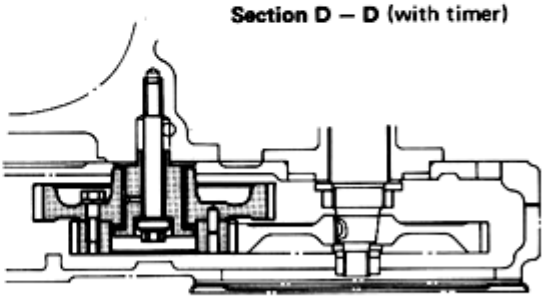
Section B – B



Section C – C

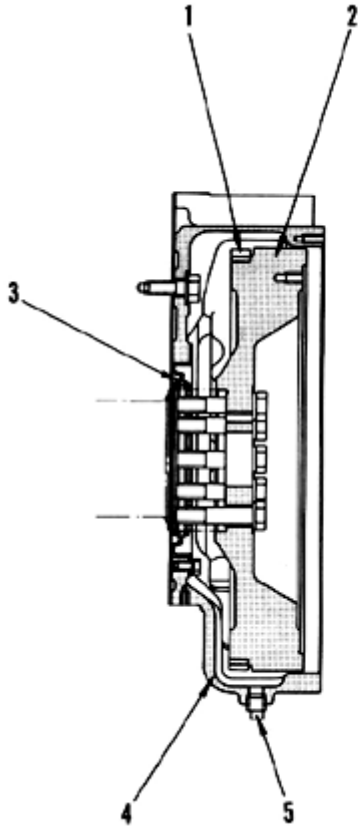


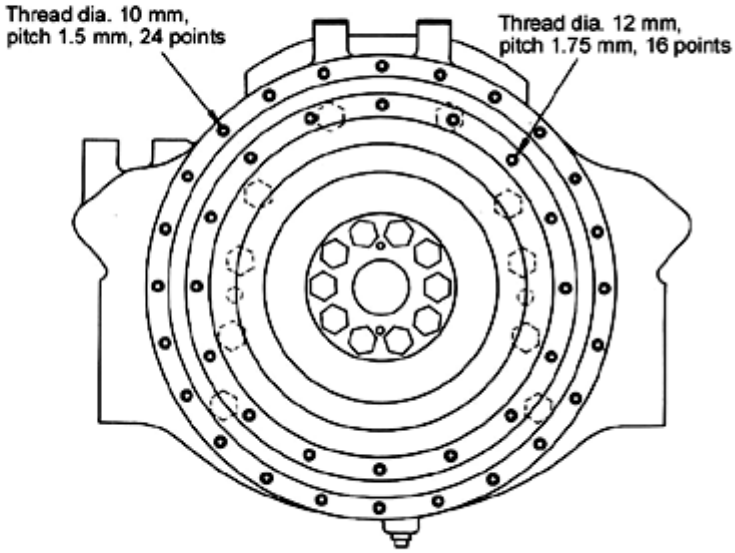
Section D – D (with timer)



Section D – D (without timer)

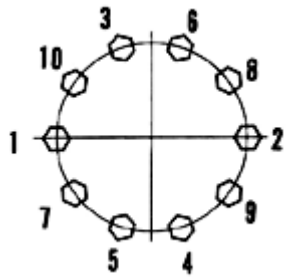
FLYWHEEL AND FLYWHEEL HOUSING





1. Ring gear
2. Flywheel
3. Rear seal
4. Flywheel housing
5. Drain plug

Tightening order of flywheel mounting bolt

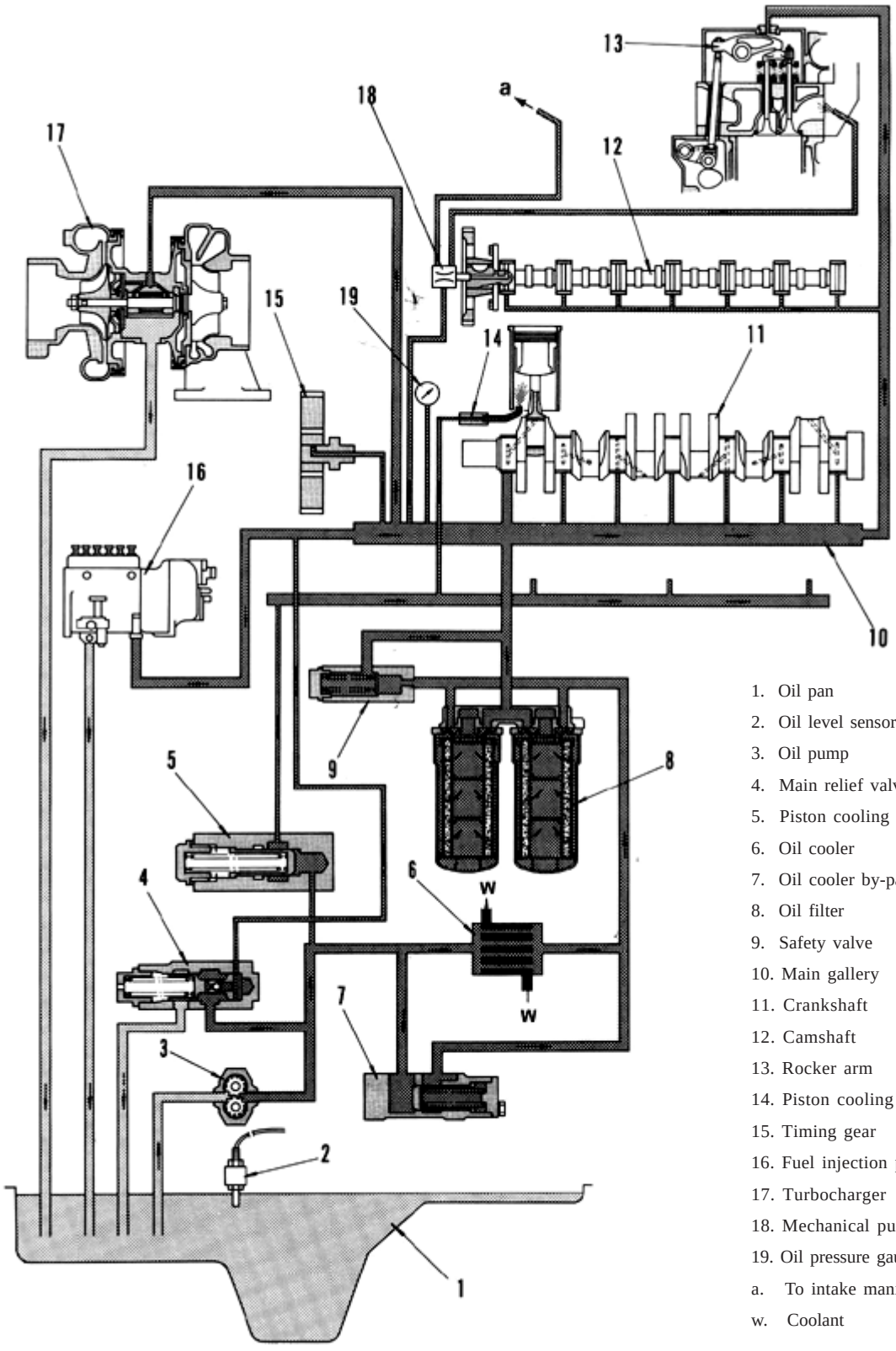


Ring gear

No. of teeth	Applicable machine
118	BE1000
138	BD355A BD155

LUBRICATION SYSTEM

LUBRICATION SYSTEM CHART

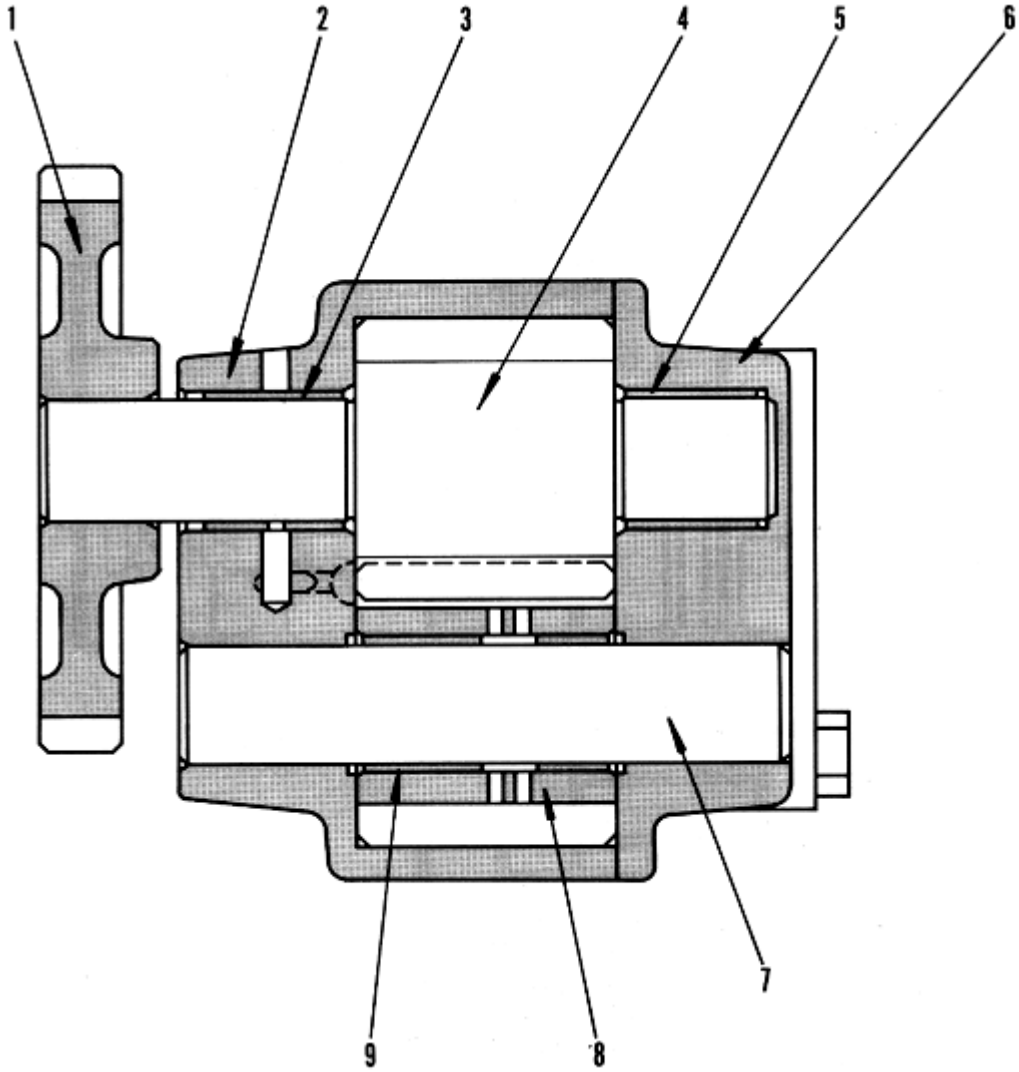


1. Oil pan
2. Oil level sensor
3. Oil pump
4. Main relief valve
5. Piston cooling valve
6. Oil cooler
7. Oil cooler by-pass valve
8. Oil filter
9. Safety valve
10. Main gallery
11. Crankshaft
12. Camshaft
13. Rocker arm
14. Piston cooling nozzle
15. Timing gear
16. Fuel injection pump
17. Turbocharger
18. Mechanical pump
19. Oil pressure gauge

a. To intake manifold

w. Coolant

OIL PUMP



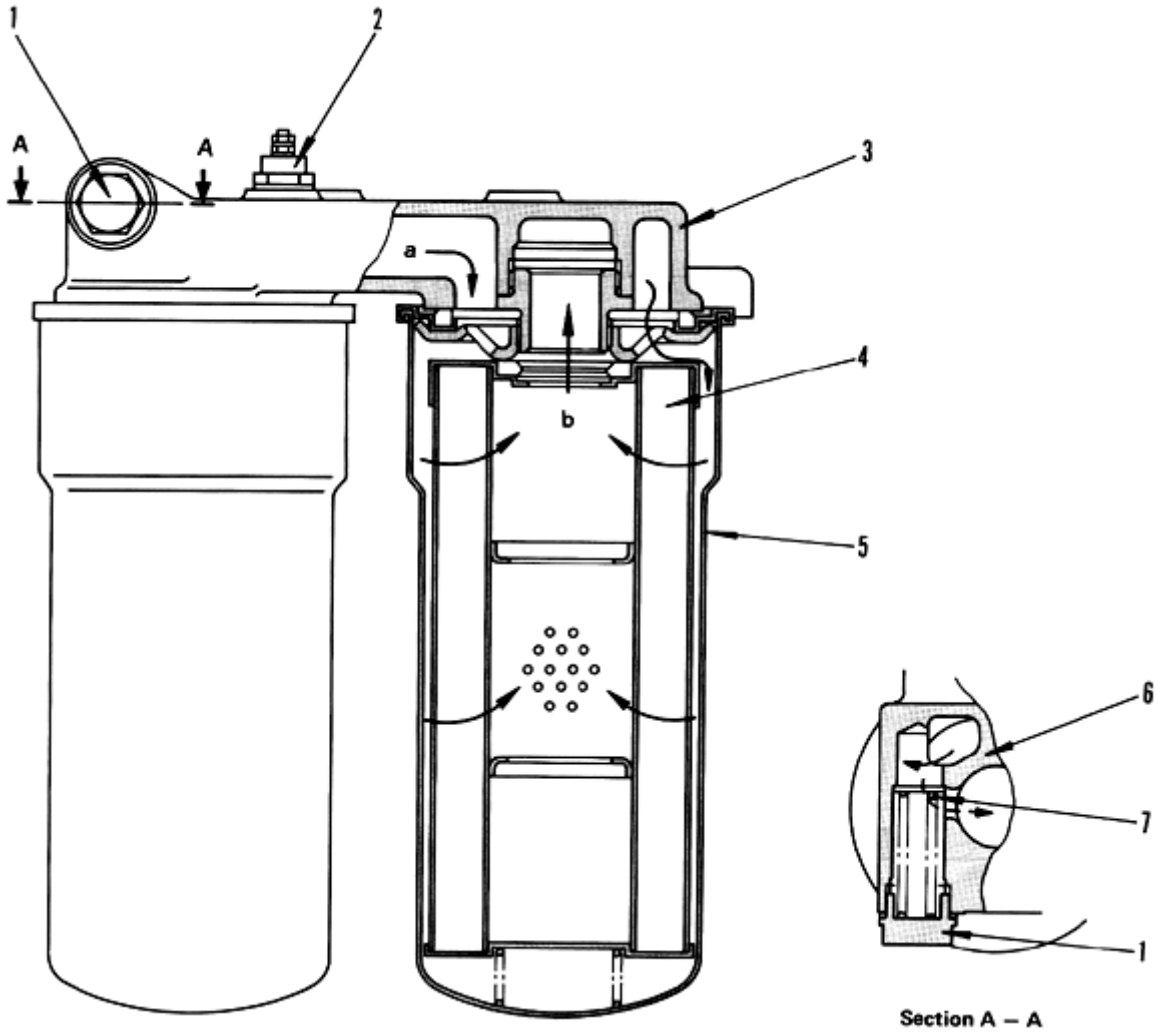
1. Oil pump driving gear (No. of teeth: 33)
2. Oil pump body
3. Bushing
4. Drive shaft
5. Bushing
6. Pump cover
7. Driven shaft
8. Driven gear (No. of teeth: 12)
9. Bushing

Oil pump

. Gear Pump type

. Oil pump speed: Engine speed x 1.091

OIL FILTER AND SAFETY VALVE



1. Safety valve cap
2. Oil pressure sensor
3. Filter bracket
4. Filter element

Cartridge

5. Filter case
6. Safety valve
7. Valve spring

a. From oil pump

b. To engine each component

Oil filter

. Filteration area: 0.82m² x 2

Safety valve

. Cracking pressure (difference pressure): 2.0 ± 0.2 kg/cm²

OIL COOLER

BS6D170-1

BSA6D170-1

1. Cooler cover
2. Cooler element
3. Drain cock

a. Coolant (from water pump)

b. Oil (from oil pump)

c. Oil (to engine each component)

Oil cooler

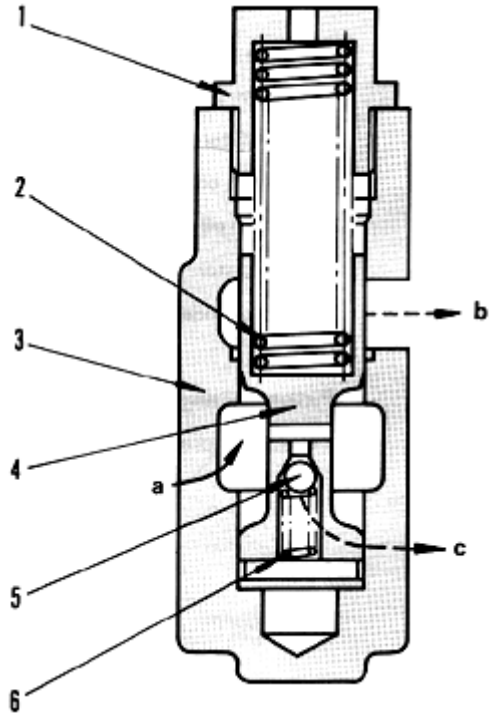
. Heat exchanged: Min. 45000 Kcal/hr.

. Heat-transmitting area: 2.94 m^2

. Oil flow capacity: 180 litre/min.

. Water flow capacity: 890 litre/min.

OIL PUMP RELIEF VALVE



1. Plug
2. Valve spring
3. Valve body
4. Relief valve
5. Ball type valve
   (Main relief valve)
6. Main relief valve spring

a. From oil pump

b. To oil pan

c. From main gallery

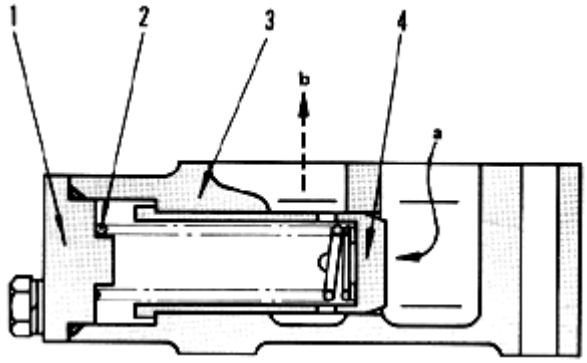
Main relief valve

. Cracking pressure (difference pressure):
  8 ± 1 kg/cm²

Oil-line check valve

. Cracking pressure: 3.3 ± 0.3 kg/cm²

OIL COOLER BY-PASS VALVE



1. Cap
2. Valve spring
3. Valve body
4. By-pass valve

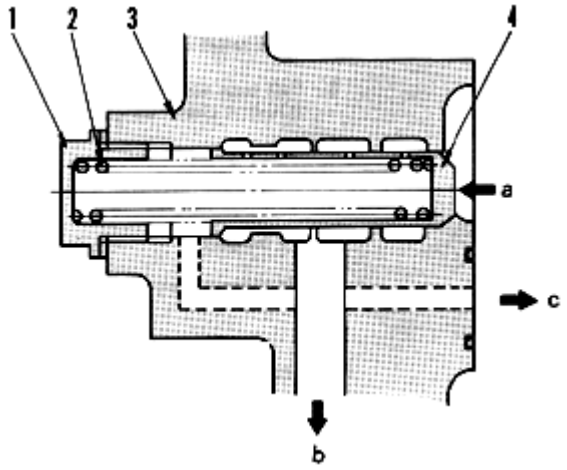
a. From oil pump

b. To oil filter

Oil cooler by-pass valve

. Cracking pressure: 4.5 ± 0.5 kg/cm²

PISTON COOLING VALVE



1. Cap
2. Valve spring
3. Oil filter adapter
4. Piston cooling valve

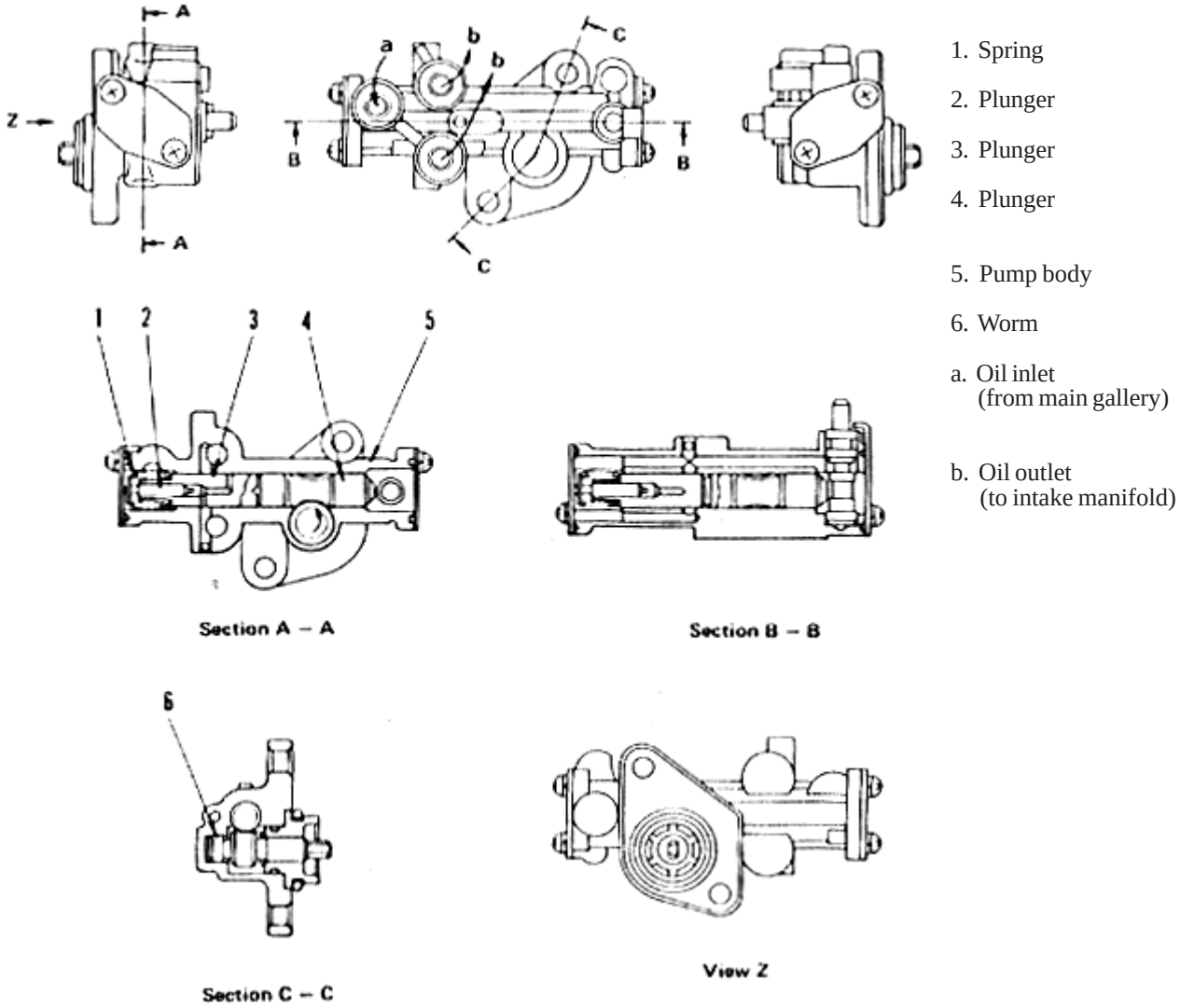
a. From oil pump

b. To piston cooling nozzle

c. To cylinder block

Piston cooling valve
. Cracking pressure: 1.3 $^{+0.3}_{-0.1}$ kg/cm²

MECHANICAL PUMP



1. Spring
2. Plunger
3. Plunger
4. Plunger
5. Pump body
6. Worm

a. Oil inlet
(from main gallery)

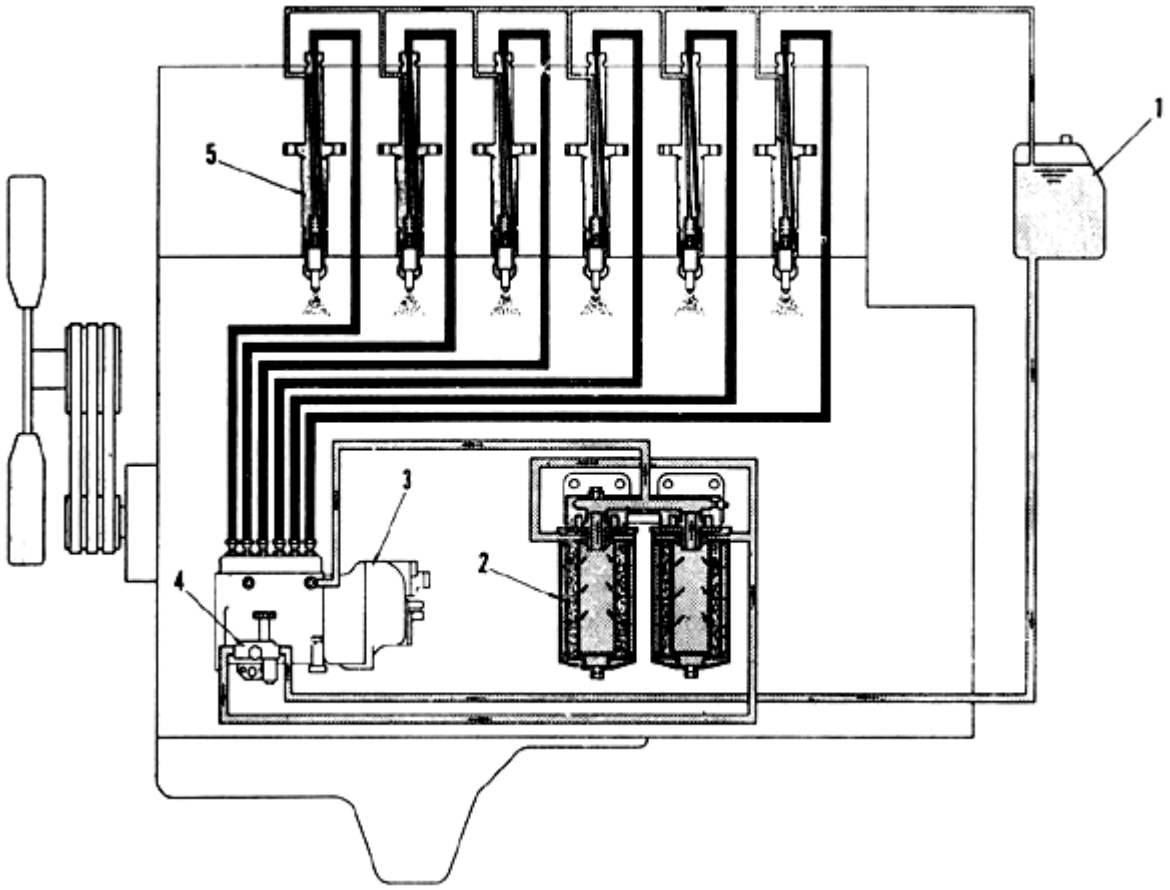
b. Oil outlet
(to intake manifold)

Mechanical pump

- Capacity: 10 ± 1 cc/h x 2
- The mechanical pump is a worm pump used to increase the wear resistance of the intake valve seat.
- The pump is driven by the slit shaft connected to the camshaft.
- The oil is sent from the main gallery into the pump and sent out from the two outlets of the pump to the two intake manifolds through the oil tubes. The oil is sprayed in the intake manifolds by the intake air onto the seats of the valves to reduce the wear of the seats.

FUEL SYSTEM

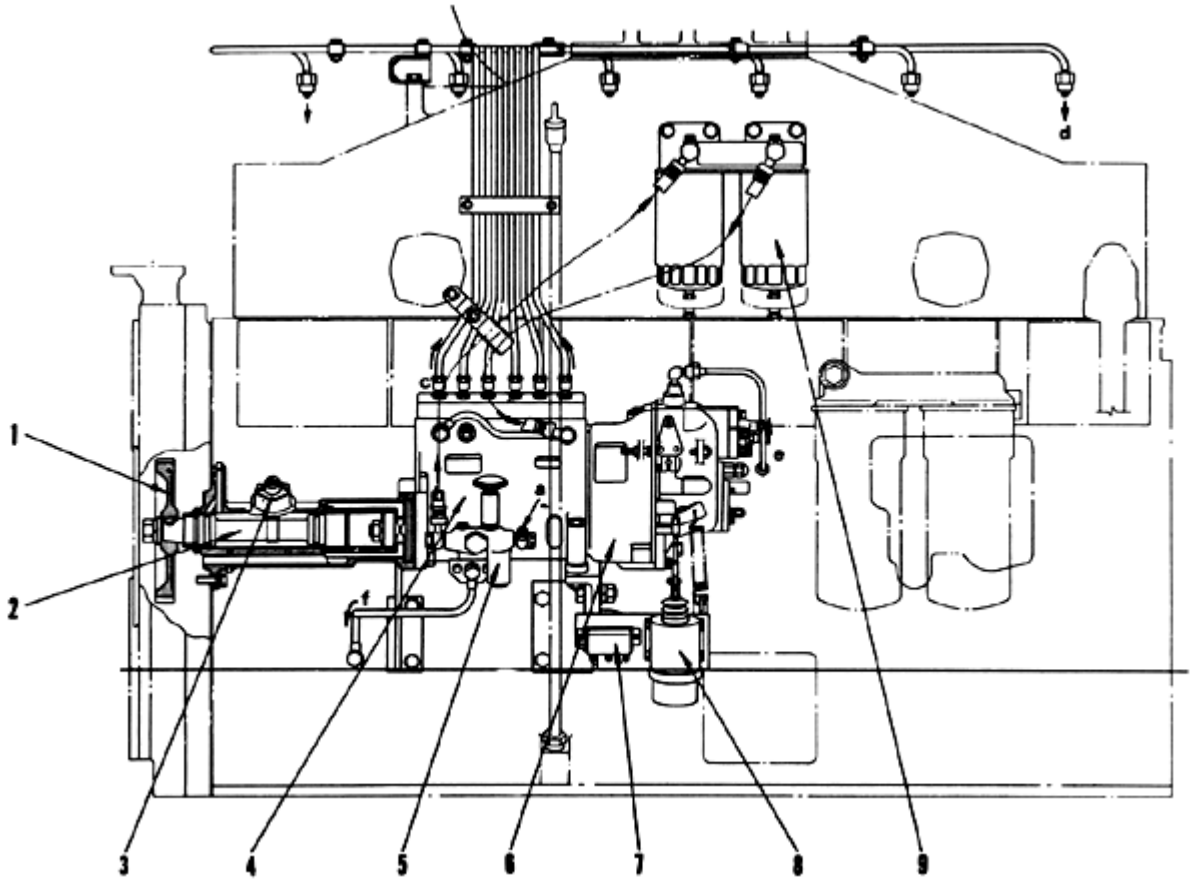
FUEL SYSTEM CHART



1. Fuel tank
2. Fuel filter
3. Fuel injection pump
4. Feed pump
5. Fuel injection nozzle

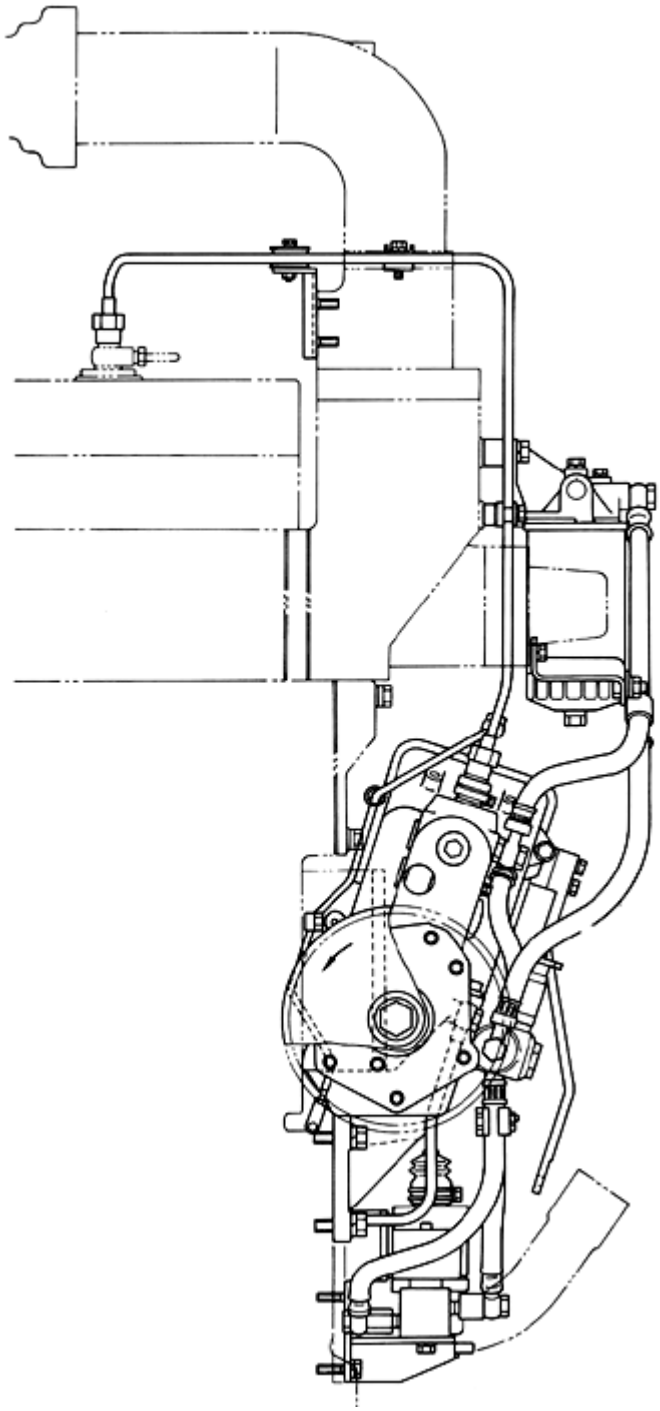
FUEL INJECTION PUMP

BS6D170-1, BSA6D170-B-1



1. Injection pump driving gear (No. of teeth: 48)
2. Injection pump drive shaft
3. Service meter output
4. Fuel injection pump
5. Feed pump
6. Governore.
7. Relay
8. Solenoid
9. Fuel filter

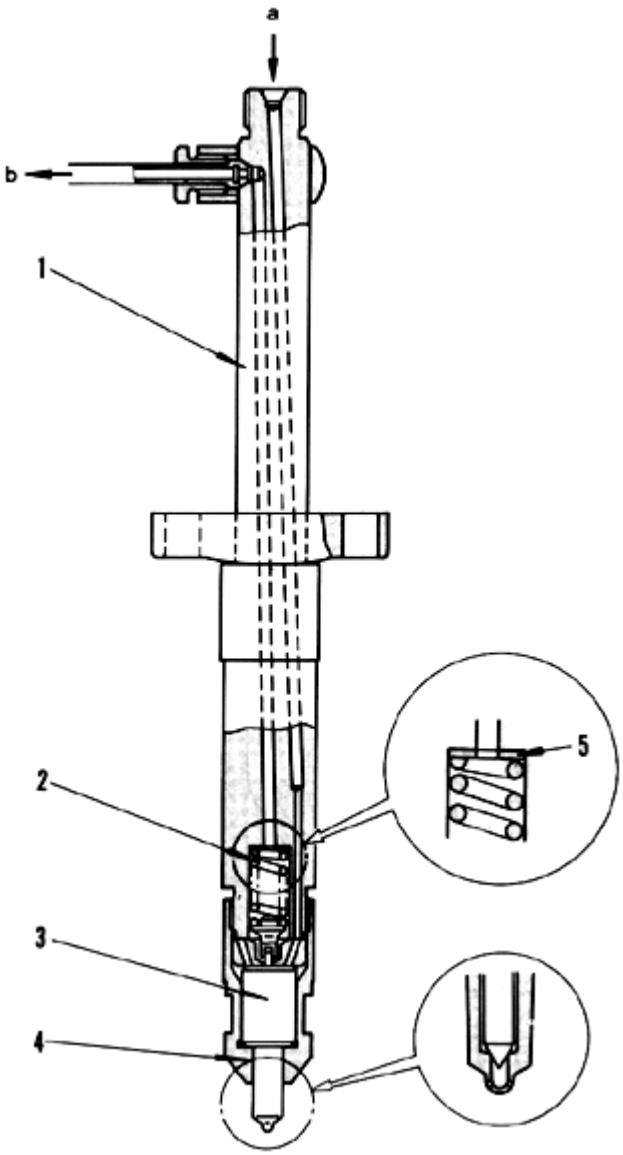
a. Fuel (from fuel tank)
b. Fuel (to fuel filter)
c. Fuel (from injection pump)
d. Fuel (to nozzle holder)
e. Oil (from main gallery)
f. Oil (to oil pan)



Fuel injection pump

. Marker : Diesel Kiki
. Type : PES-PD type
. Governor : RSUV, centrifugal type, all-peed type
. Lubrication method : Forced lubrication with engine oil

FUEL INJECTION NOZZLE



1. Nozzle holder
2. Nozzle spring
3. Nozzle
4. Retaining cap
5. Adjustment shim

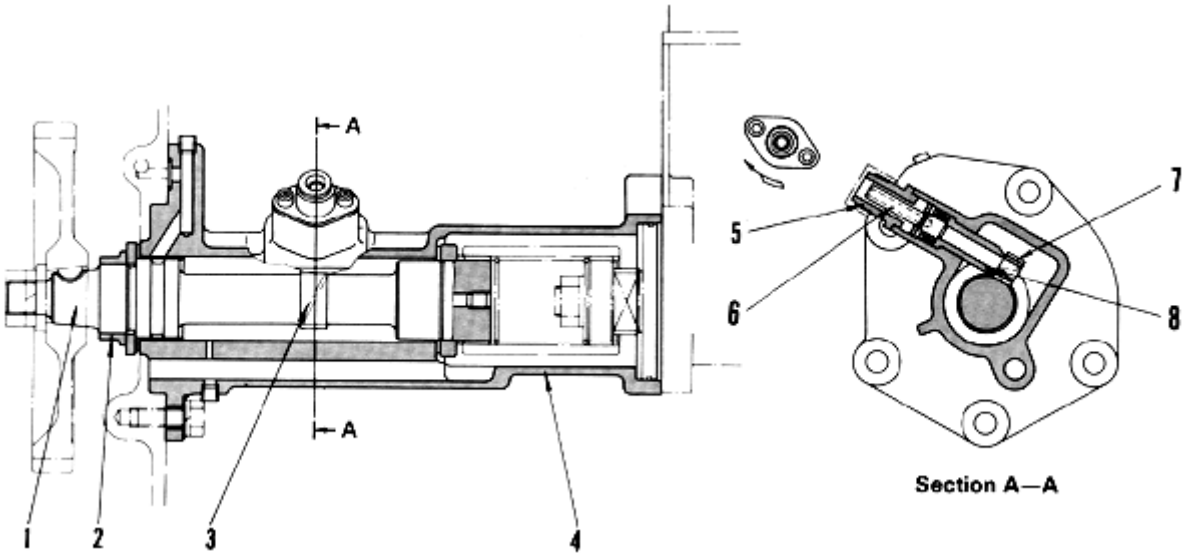
a. Fuel inlet

b. Fuel return (To fuel tank)

Fuel injection nozzle
. Marker: Diesel Kiki
. Type: Bosch DLL-S type, multiple hole type

FUEL INJECTION PUMP DRIVE

For PES-PD type injection pump

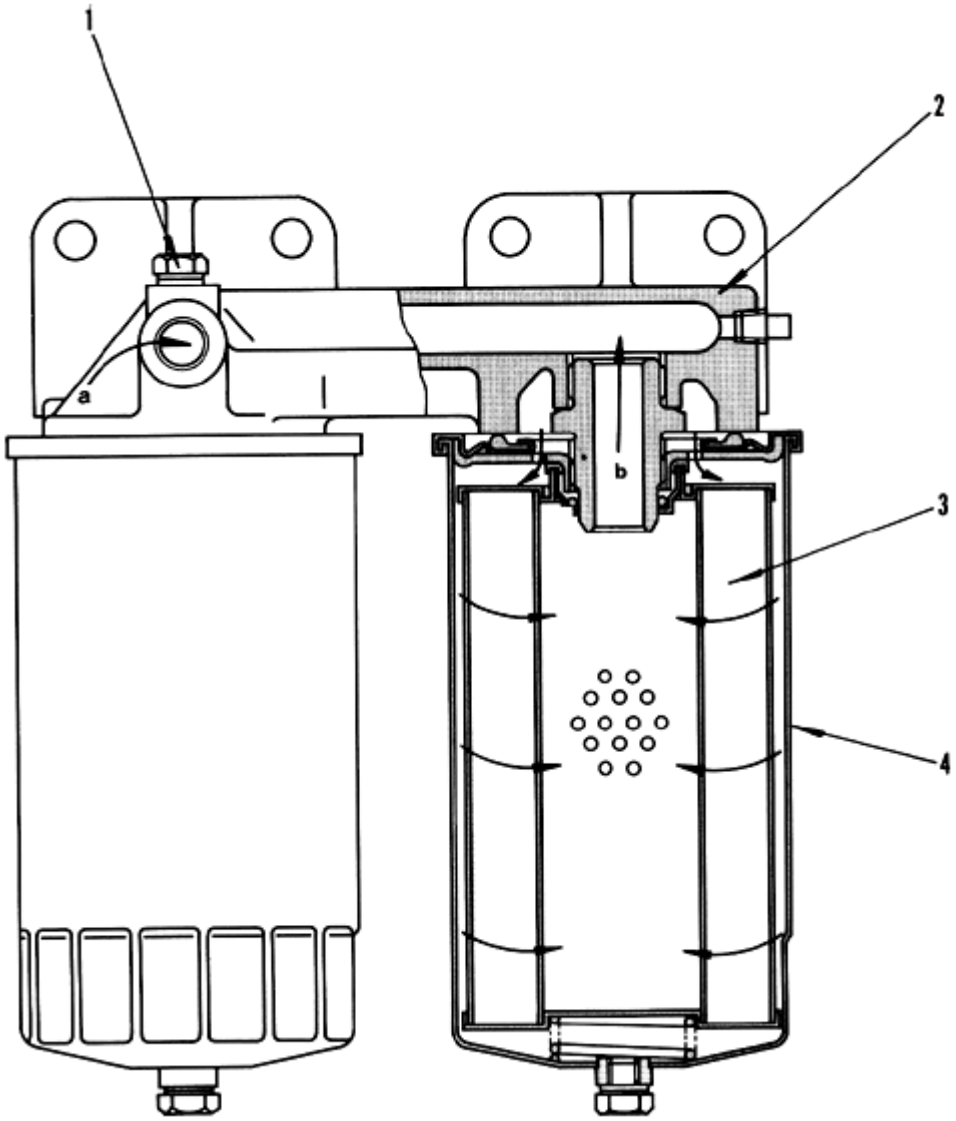


1. Fuel injection pump drive shaft
2. Nut
3. Tachometer drive gear (No. of teeth: 14)
4. Drive housing
5. Pinion gear housing
6. Tachometer drive shaft
7. Pinion gear (No. of teeth: 14)
8. Bushing

Tachometer drive

. Tachometer drive shaft speed = Engine speed x 1/2

FUEL FILTER



1. Air bleeding plug
2. Filter bracket
3. Filter element } Cartridge
4. Filter case
a. From feed pump
b. To fuel injection pump

Fuel filter

. Filtration area: 0.4m² x 2

STARTING AID

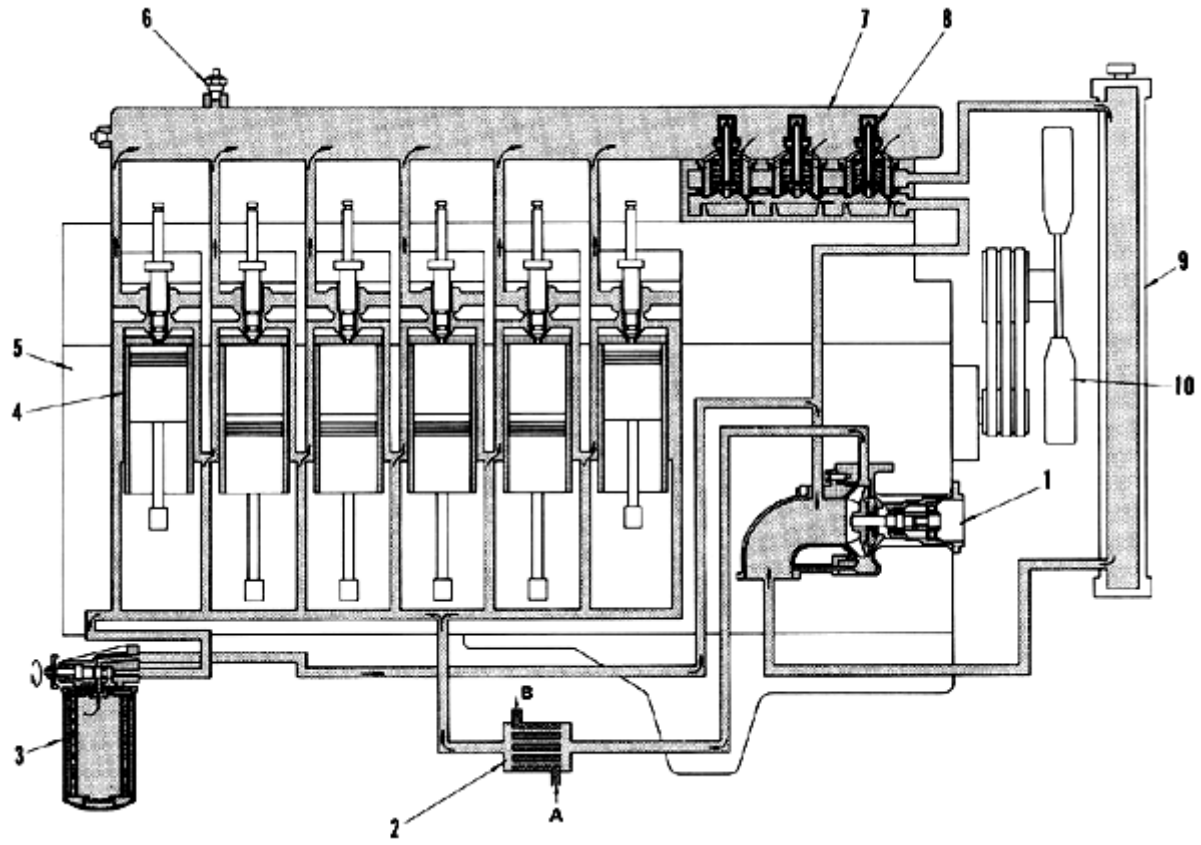
AUTO PRIMING SYSTEM (APS)

1. Glow plug
2. Clamp
3. Wiring harness
4. Cover
5. Nozzle
6. Hose
7. Bracket
8. Hose
9. Valve

a. To heater switch
b. To APS controller
c. To APS controller
d. To heater switch
e. From fuel filter (fuel)

COOLING SYSTEM

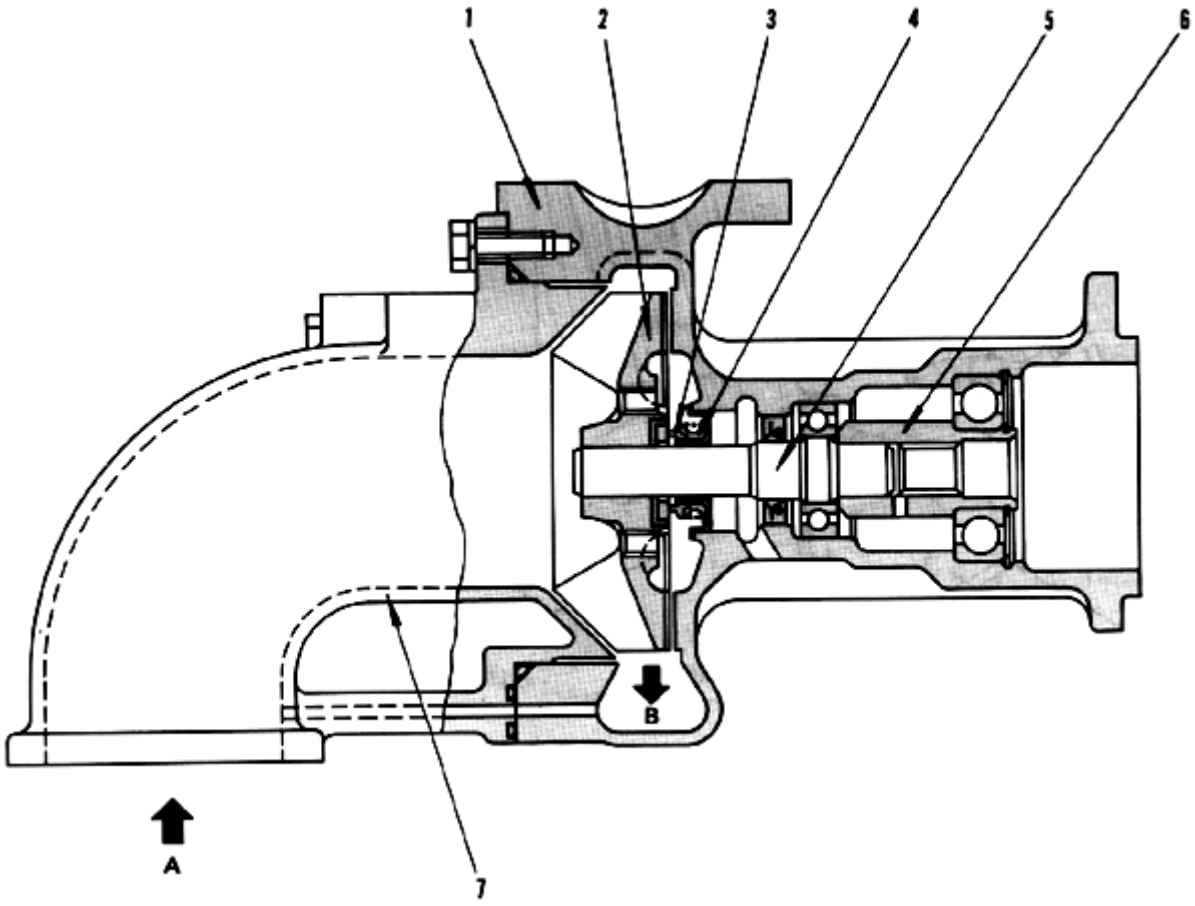
COOLING SYSTEM CHART



1. Water pump
2. Oil cooler
3. Corrosion resistor
4. Cylinder liner
5. Cylinder block
6. Thermostat switch
7. Water manifold
8. Thermostat
9. Radiator
10. Fan

A. From oil pump (oil)
B. To engine each component (oil)

WATER PUMP



1. Pump body
2. Impeller
3. Floating seal
4. Water seal
5. Pump shaft (rear)
6. Pump shaft (front)
7. Inlet housing

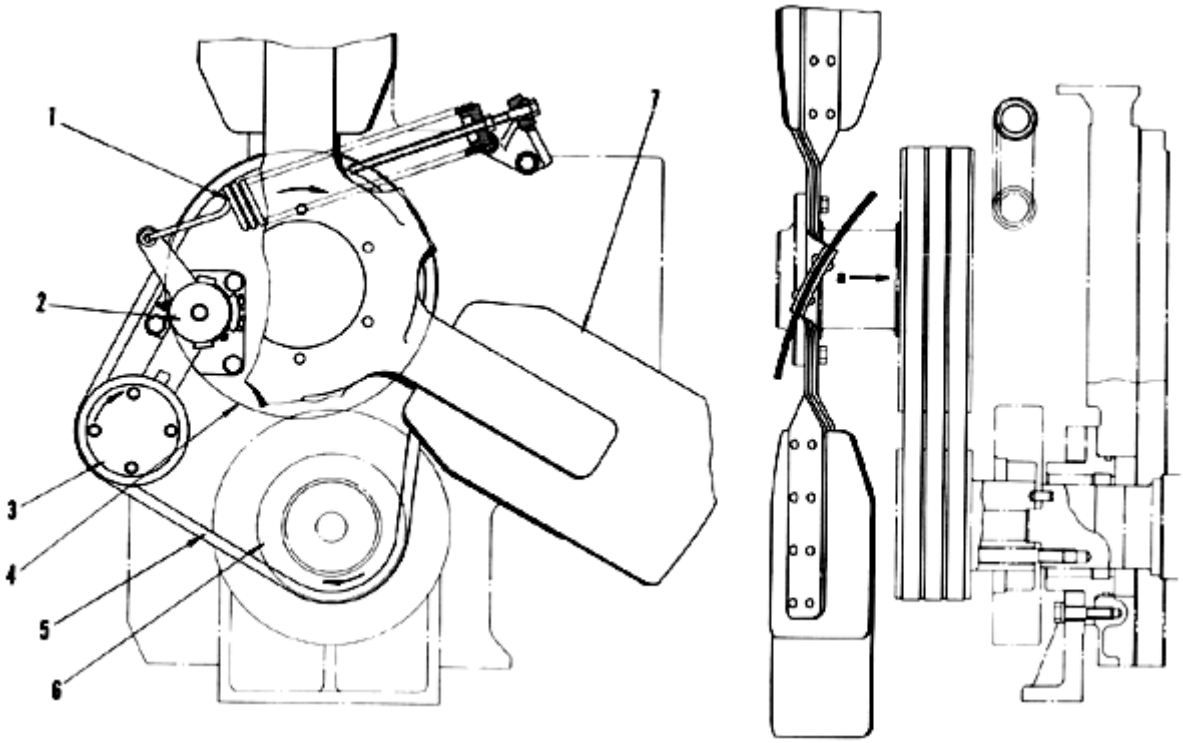
A. From radiator
B. To oil cooler

Water pump

. Water pump speed =Engine speed x 1.8
. Flow capacity: 1050 liter/min. (3,600 rpm)

FAN DRIVE AND TENSION PULLEY

. FAN DRIVE (for BE1000)

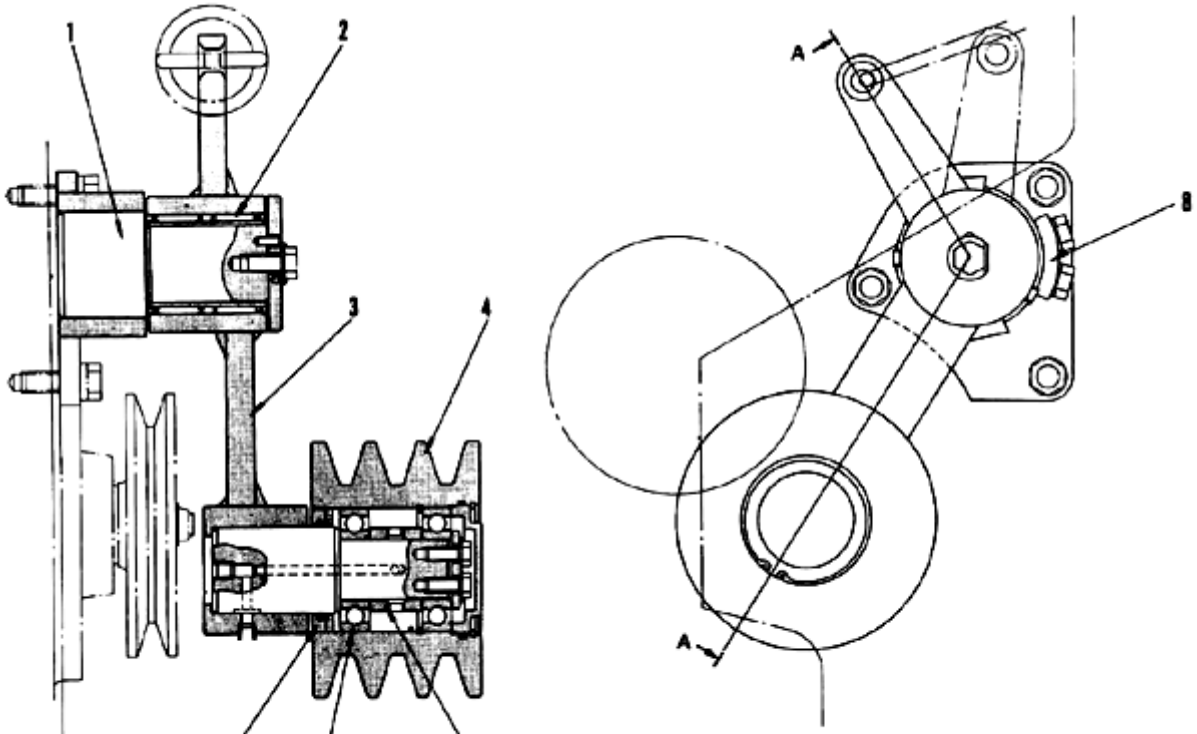


1. Tension spring
2. Tension shaft
3. Tension pulley
4. Fan pulley
5. Fan belt
6. Crankshaft pulley
7. Fan

Outside diameter for pulley Unit : mm

Applicable machine	Fan pulley	Crankshaft pulley	Tension pulley
BE1000	347	200	150

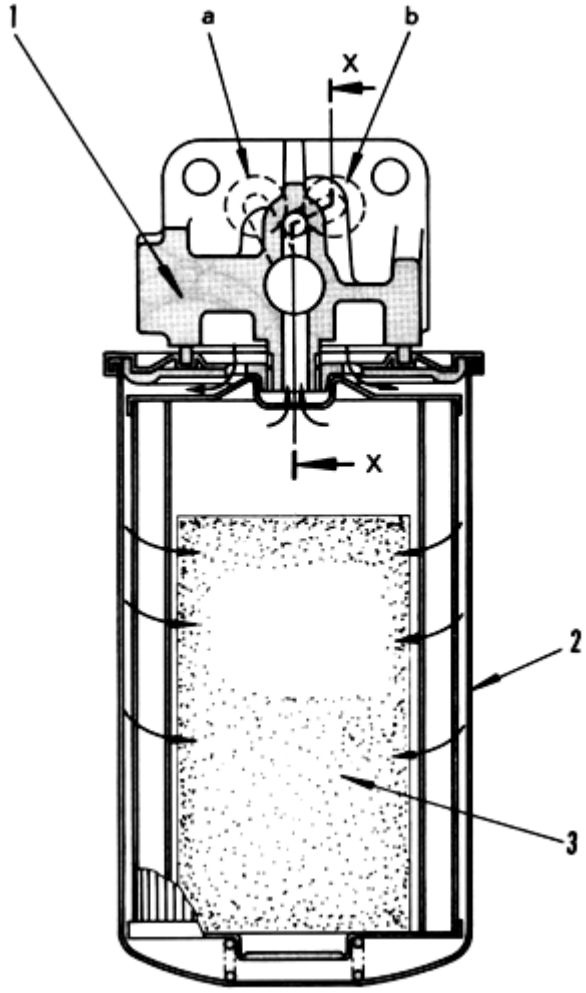
. TENSION PULLEY (For BE1000)

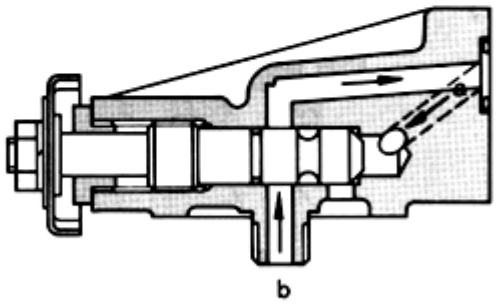


Section A – A

1. Tension pulley shaft
2. Roller bearing
3. Tension pulley bracket
4. Tension pulley (Outside diameter: 150 mm)
5. Oil seal
6. Ball bearing
7. Spacer
8. Stopper

CORROSION RESISTOR





Section X – X (Detail valve)

1. Head
2. Element case
3. Solid drug (included 1,000g)

} Cartraidge

a. Coolant inlet

b. Coolant outlet

Corrosion resistor

- Filteration area: 0.13 m²

THERMOSTAT

1. Seal
2. Thermostat
3. Valve
4. Body
5. Piston
6. Sensor
7. Sleeve
8. Wax

a. From engine each component

b. To water pump

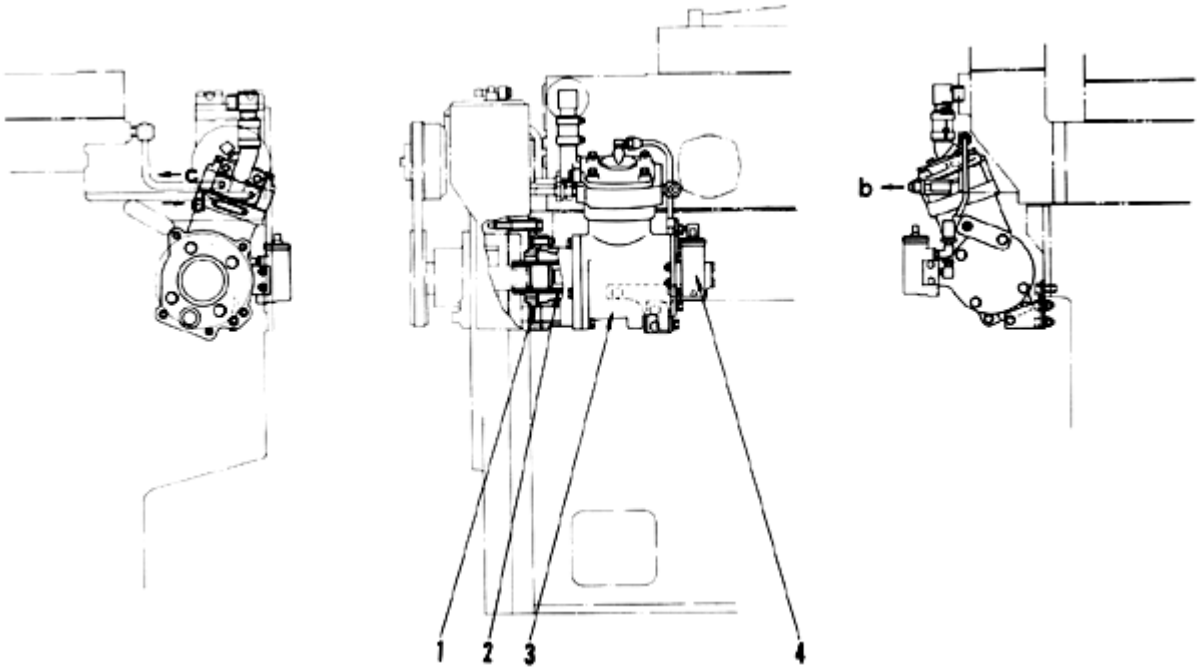
c. To radiator

OPERATION

Function

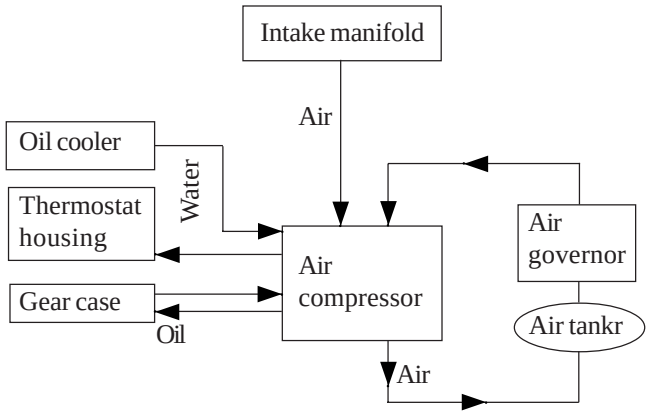
. Opening temperature: 76.5 ± 2°C
. Full opening temperature: 90° C
. Valve lift: Minimum 10 mm

ACCESSORY
AIR COMPRESSOR MOUNTING



1. Flange
2. Coupling
3. Air compressor
4. Air governor

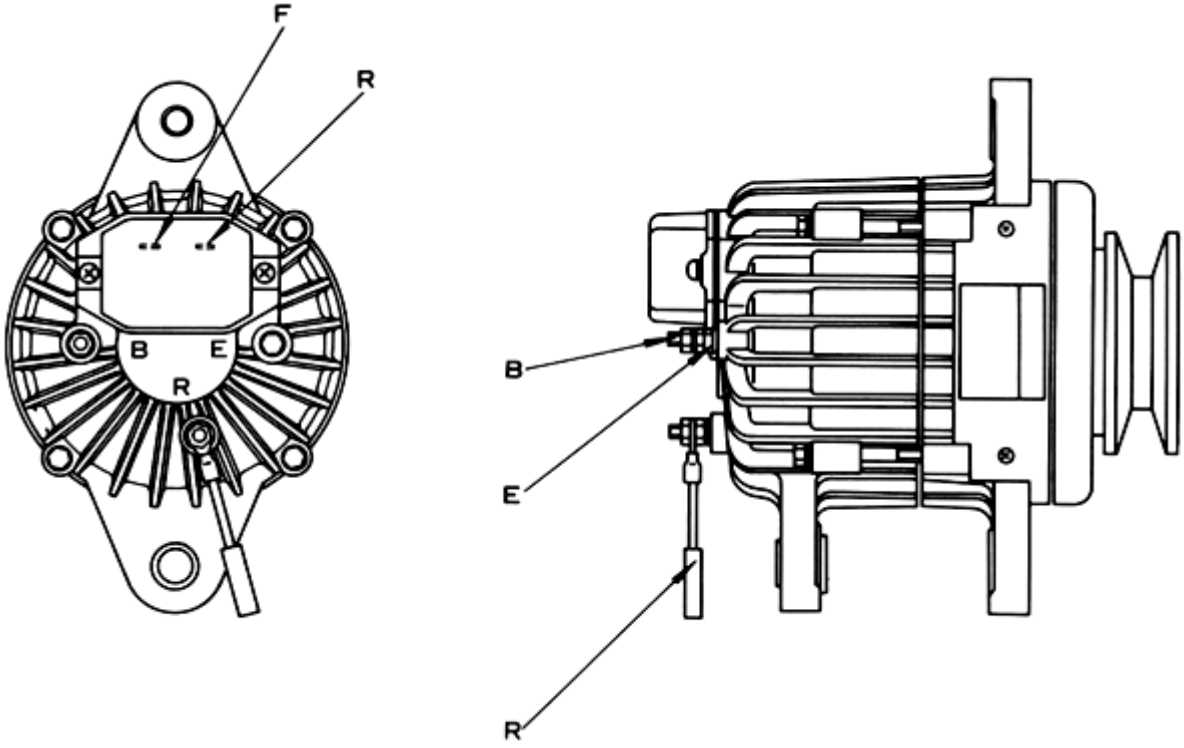
a. From intake manifold (air)
b. To air tank (air)
c. To thermostat housing (cooling water)
d. From oil cooler (cooling water)

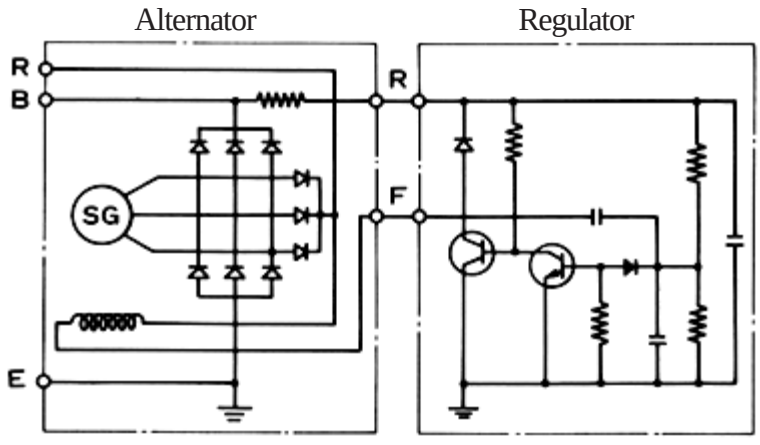


Air circuit diagram

ELECTRICAL SYSTEM

ALTERNATOR WITH REGULATOR



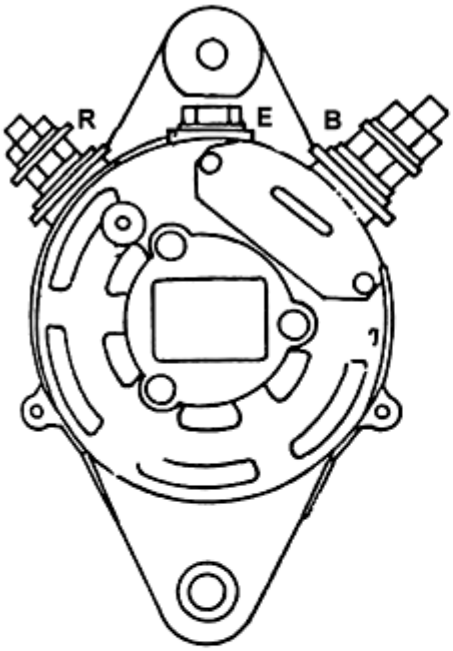


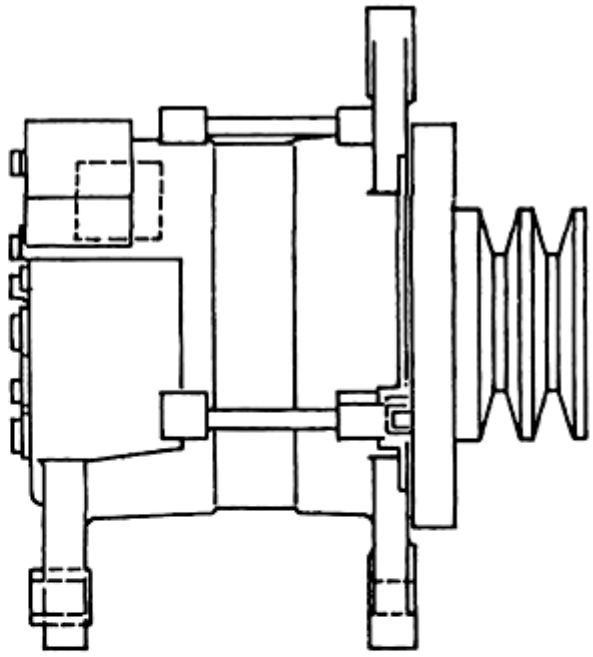
B.E.F.R: Terminal

Wiring diagram

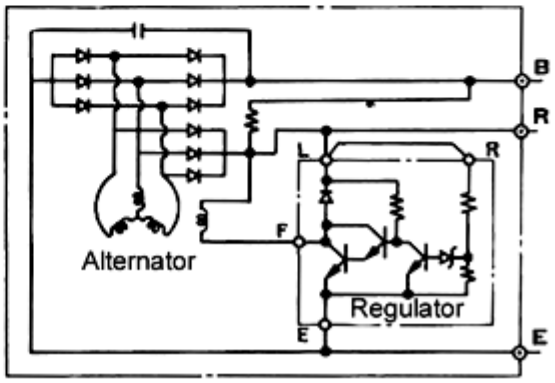
Engine	Applicable machine model	Type	Specifications	Pulley outside diameter (mm)	Weight (kg)
BS6D170-1	BD155	Nikko Denki, Open type	24V, 50A	95	9.5
	BD355	Nikko Denki, Closed type	24V, 13A	95	9.5

ALTERNATOR BUILT-IN REGULATOR





1. Alternator
2. Regulator

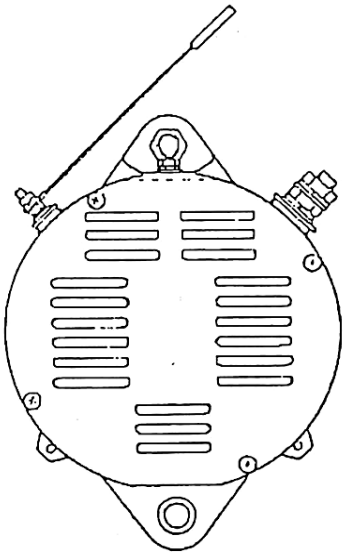


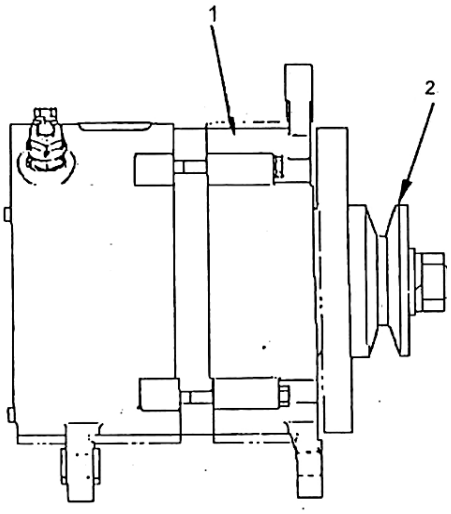
Wiring diagram

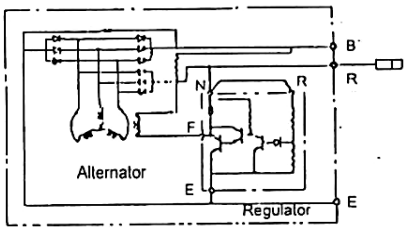
Engine	Applicable machine model	Type	Specifications	Pulley outside diameter (mm)	Weight (kg)
BSA6D170-1	BE1000	Nikko Denki, Open type	24V, 50A	95	12

ALTERNATOR

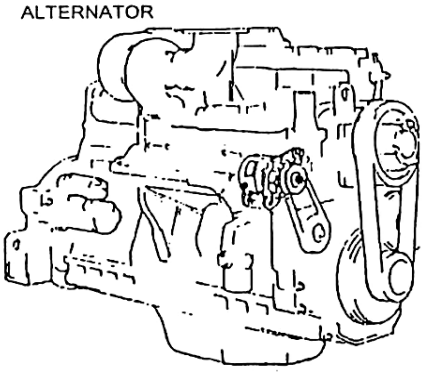
For BH60,BH70 & 210M







Wiring diagram

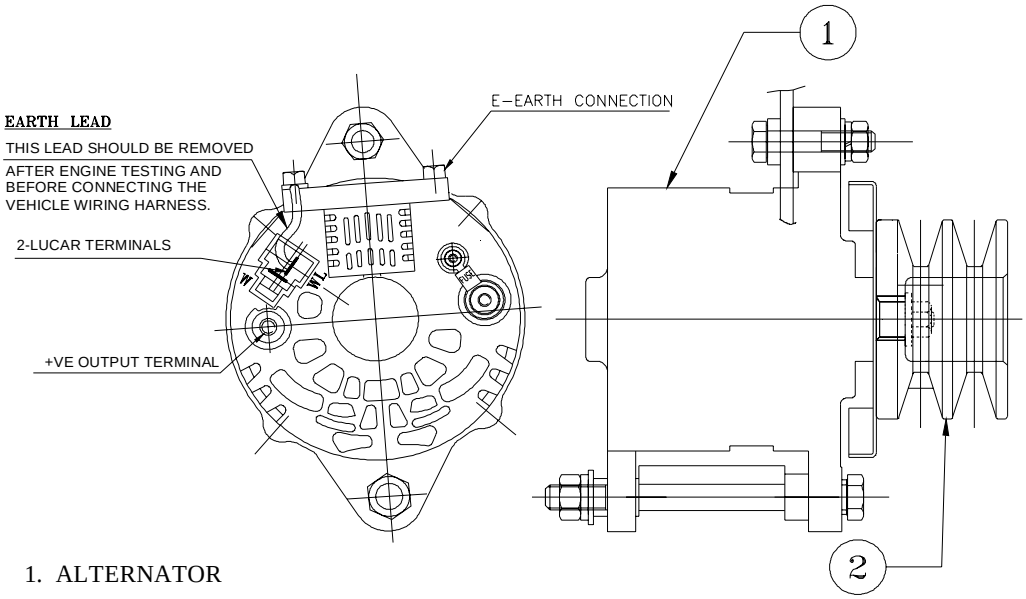


1. Alternator
2. Alternator pull

B.E.F.R: Terminal

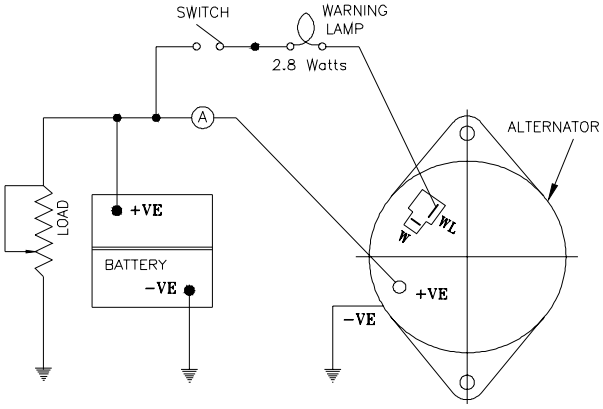
Engine	Applicable machine model	Type	Specifications	Pulley outside diameter (mm)	Weight (kg)
BSA6D170A-1	BH60	SAWAFUJI	24V, 50A	95	12
	BH70	SAWAFUJI	24V, 50A	95	12
	210M	SAWAFUJI	24V, 50A	95	12

BDG500, BDG550



1. ALTERNATOR
2. ALTERNATOR PULLEY.

TERMINAL	SIZE	TIGHTENING TORQUE
+VE	M8x1.25	17.3 kg.cm~23kg.cm
-VE	M6x1	17.3 kg.cm~23kg.cm
WL	LUCAR 6.35 x 0.8t	—
W	— ” —	—
W= A.C PHASE TAP TERMINAL (UNREGULATED VOLTAGE TERMINAL)		

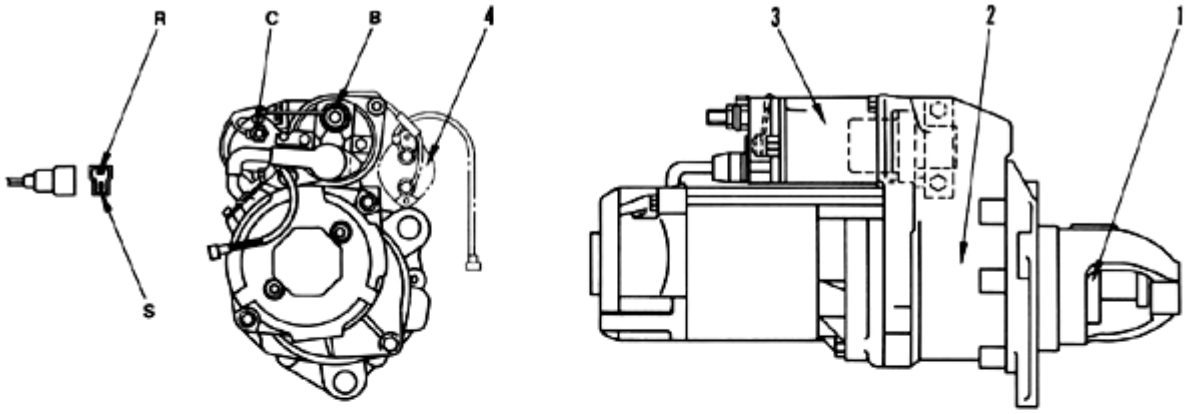


B.E.F.R: Terminal

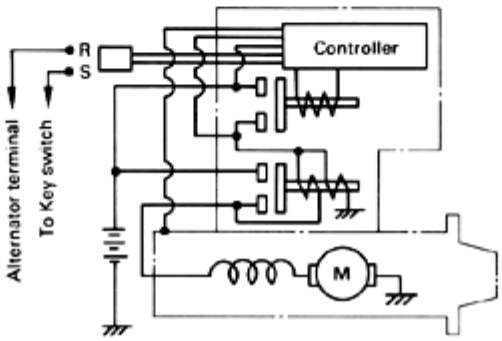
Engine	Applicable machine model	Type	Specifications	Pulley outside diameter (mm)	Weight (kg)
BSA6D170AG-1	BDG500	LUCAS TVS	24V, 30A	85	10
	BDG550	LUCAS TVS	24V, 30A	85	10

STARTING MOTOR

BD155, BD355



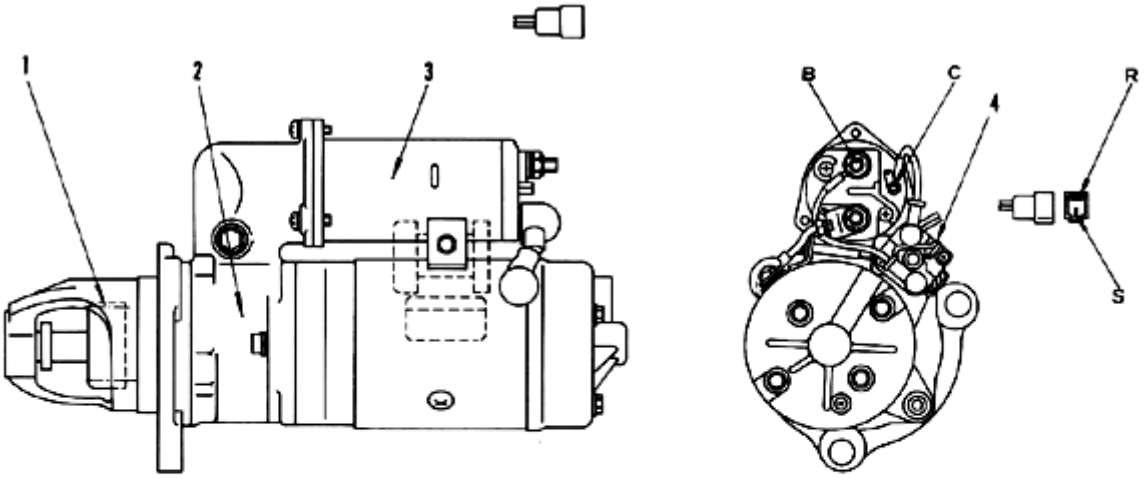
1. Pinion gear
2. Starting motor assembly
3. Magnetic switch
4. Safety relay

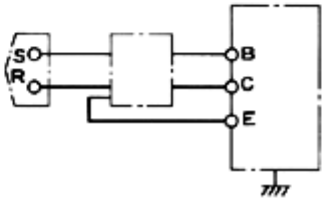


B, C, E, R, S: Terminal

Engine	Applicable machine model	Type	Specifications	Weight (kg)
BS6D170-1	BD155	SAFUge Denki, Sealed type	24V, 11KW	21.5
	BD355	SAFUge Denki, Sealed type	24V, 11KW	21.5

BE1000



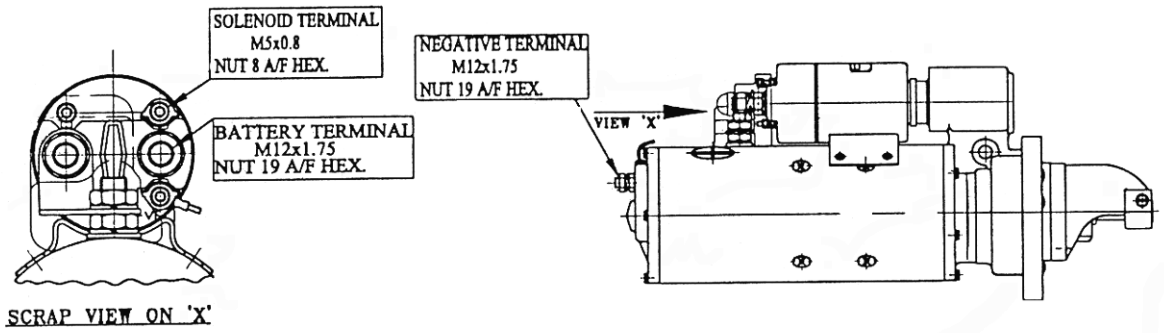


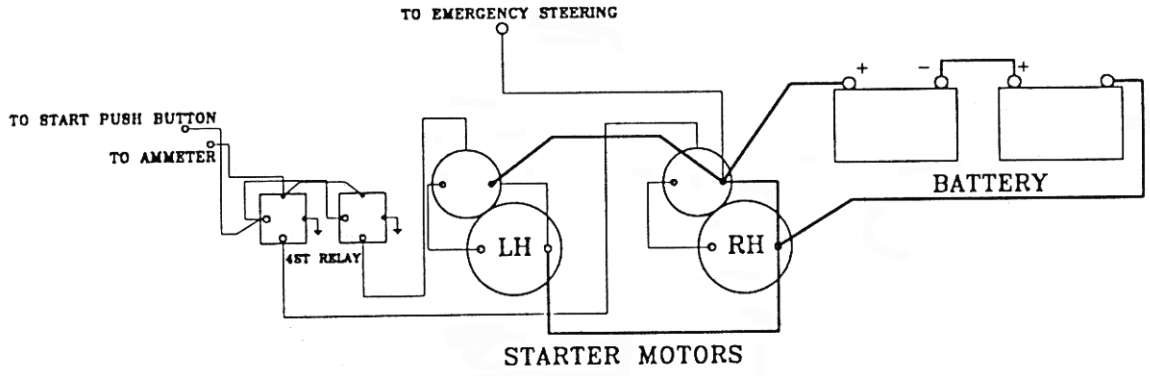
1. Pinion gear
2. Starting motor assembly
3. Magnetic switch
4. Safety relay

B, C, E, R, S: Terminal

Engine	Applicable machine model	Type	Specifications	No. of pinion teeth	Weight (kg)
BSA6D170-1	BE1000	Nikko Denki, Sealed type	24V, 7.5KW	11	18

BH60, BH70 & 210M

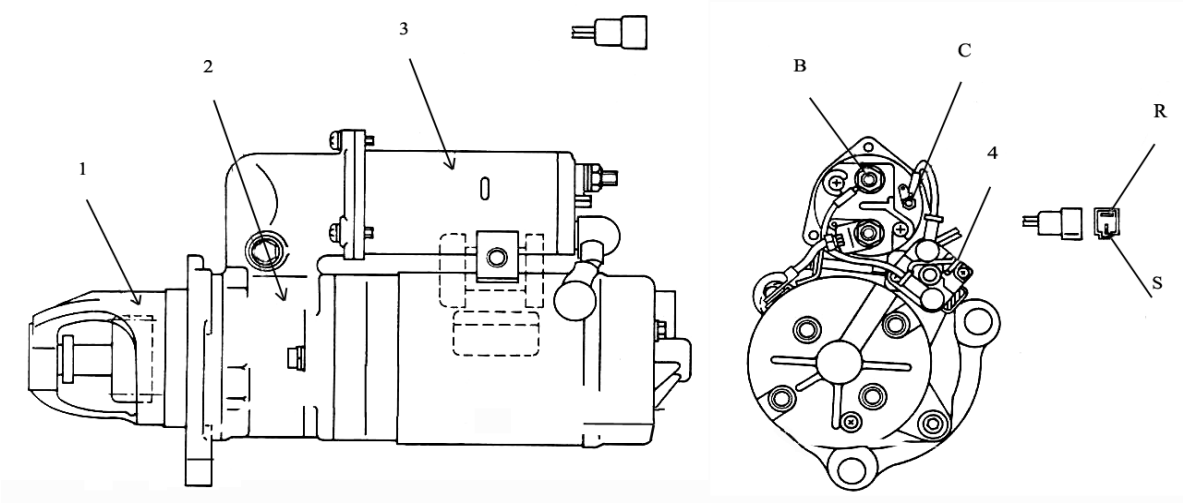




Engine	Applicable machine model	Type	Specifications	Number of Pinion teeth	Weight (kg)
BSA6D170A-1	BH60	SM130PE LUCAS TVS	24V, 7.5kW x 2	11	30
	BH70	SM130PE LUCAS TVS	24V, 7.5kW x 2	11	30
	210M	SM130PE LUCAS TVS	24V, 7.5kW x 2	11	30

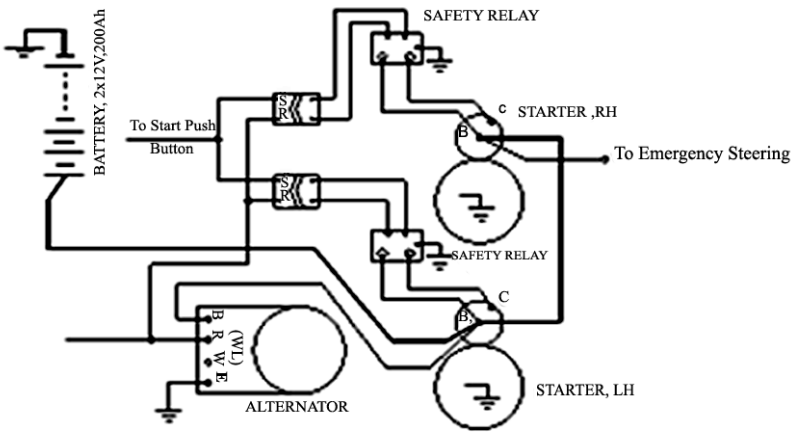
STARTER MOTOR (Nikko Denki)
For BH70

For Engine Sl. No. Z557660001



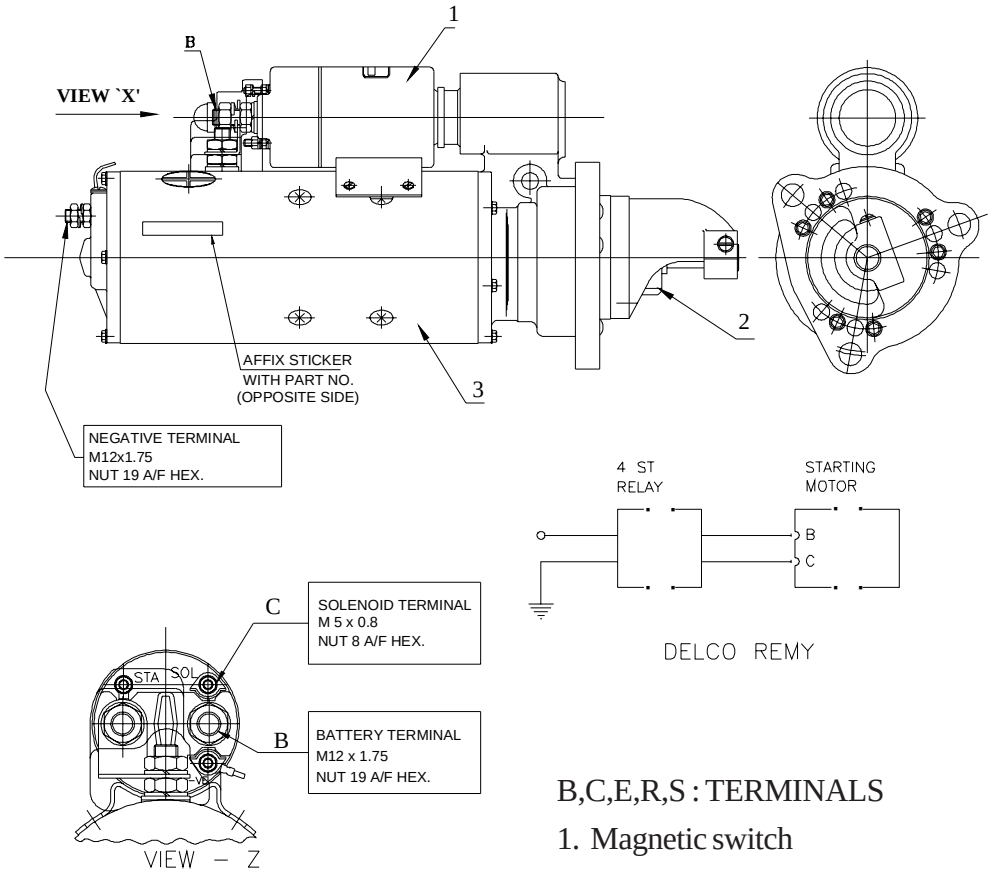
B,C,E,R,S : TERMINALS

1. Pinion gear
2. Starting motor assembly
3. Magnetic switch
4. Safety relay



Engine	Applicable machine model	Type	Specifications	Number of Pinion teeth	Weight (kg)
BSA6D170A-1	BH70	Nikko Denki, Sealed type	24V, 7.5kW x 2	11	18

BDG500, BDG550

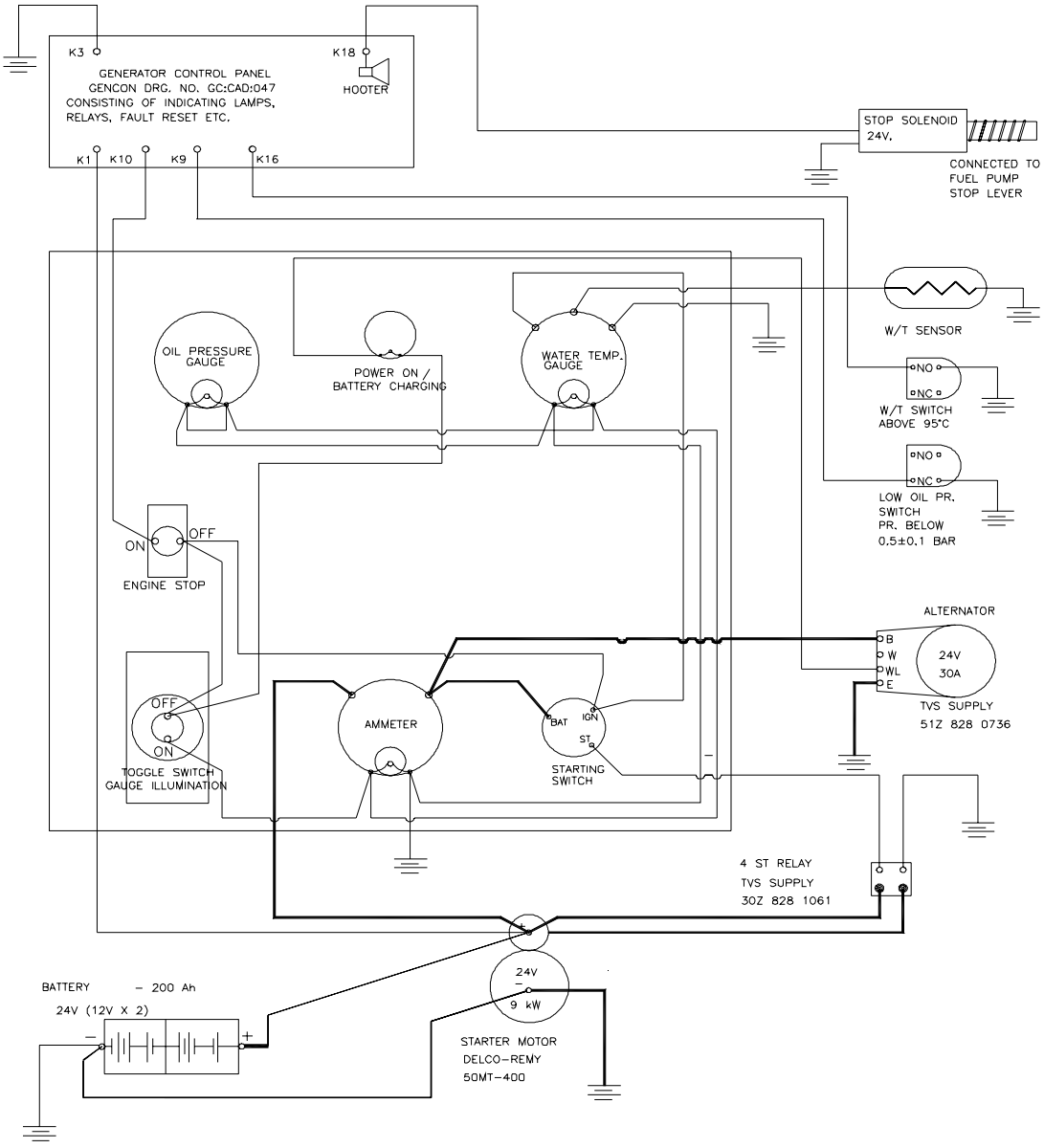


B,C,E,R,S : TERMINALS

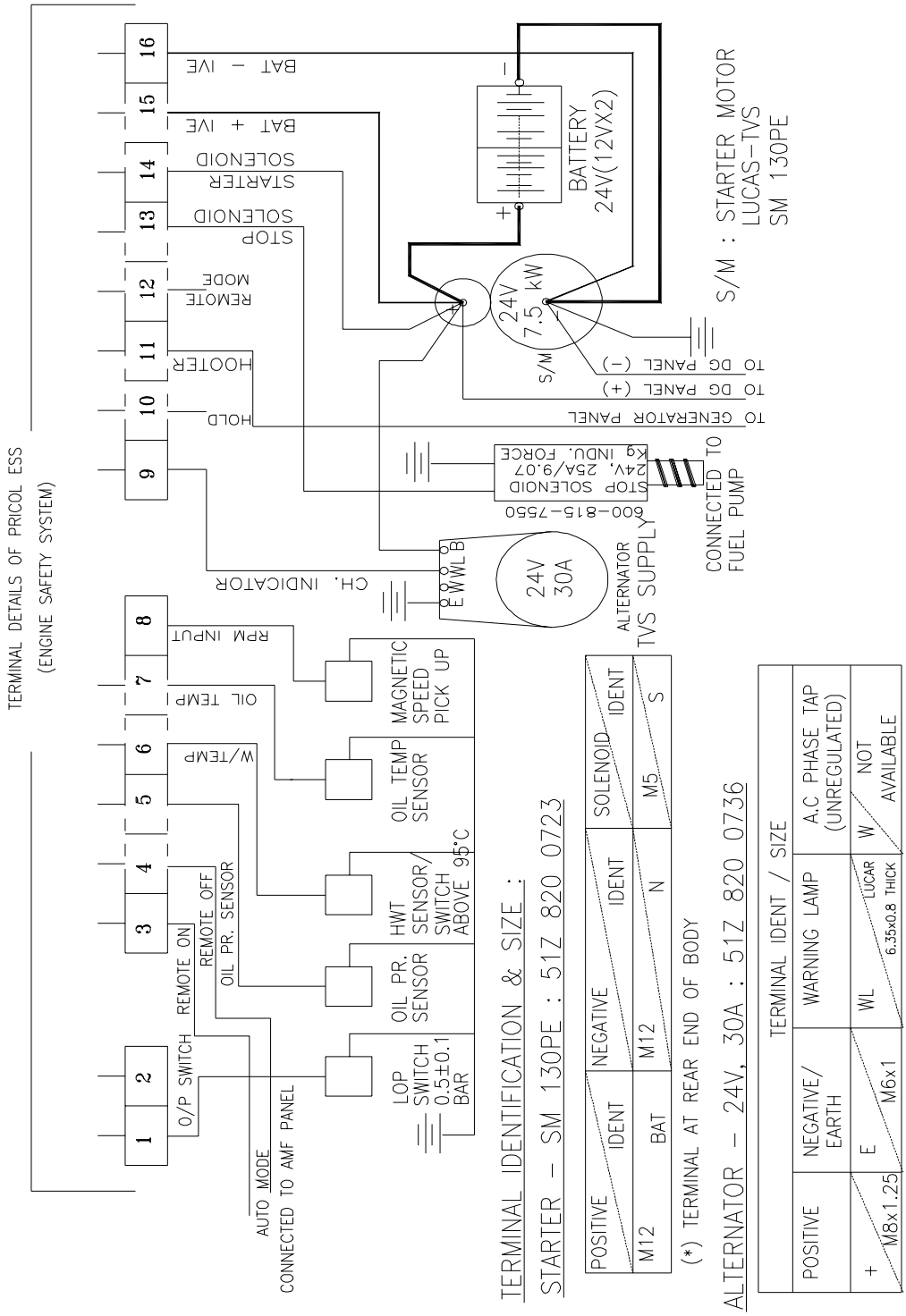
1. Magnetic switch
2. Pinion gear
3. Starting motor

Engine	Applicable machine model	Type	Specifications	Number of Pinion teeth	Weight (kg)
BSA6D170AG-1	BDG500	DELCO REMY	24V, 9kW	11	32
	BDG550	DELCO REMY	24V, 9kW	11	32

WIRING DIAGRAM (MECHANICAL GAUGES & SENSORS)
For BDG500 & BDG550 (500kVA & 550kVA DG SET ENGINES)



WIRING DIAGRAM FOR PRICOL ENGINE SAFETY SYSTEM
For 500kVA, 550kVA



ENGINE

13 TESTING AND ADJUSTING

 When carrying out testing and adjusting, or troubleshooting, stop the machine on level ground, fit safety pins, block the wheels, and apply the parking brake.

 When carrying out operations with two or more workers, always use signals, and do not allow any unauthorized person near the machine.

 When checking the water level, if the radiator cap is removed when the engine is hot, boiling water will spurt out and may cause burns, so always wait for the engine to cool down before checking the water level.

 Be extremely careful not to touch any hot parts.

 Be extremely careful not to get caught in the fan or any other rotating parts.

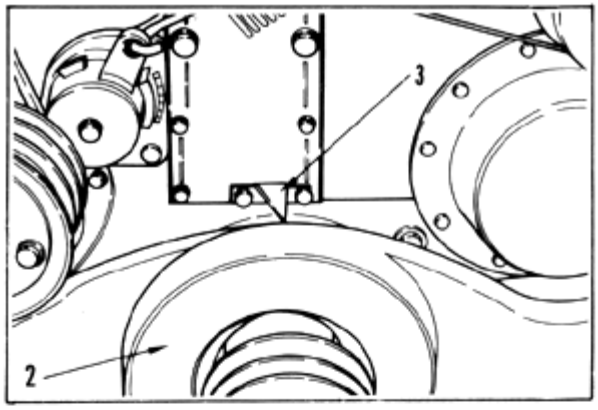
 When removing the plugs or caps from places under hydraulic pressure, water pressure, or air pressure, release the internal pressure first. Fit the measuring tools securely before carrying out any testing, adjusting, or troubleshooting.

★ When using the standard values table for judgement in testing, adjusting, or troubleshooting, it is necessary to be careful of the following points.

1. The standard values for the new machines in the standard values table are values given as reference from the standards for new machines and machines shipped from the factory. They should be used as values for estimating wear during operation or as target values when carrying out repairs.
2. The failure judgement standard values in the standard value table are values using estimated values based on the results of various tests and standard values for machines shipped from the factory. Use these values for reference together with the repair and operation history of the machine when judging failures.
3. Do not use this standard values table as a standard for judging claims.

ENGINE BODY

ADJUSTING VALVE CLEARANCE



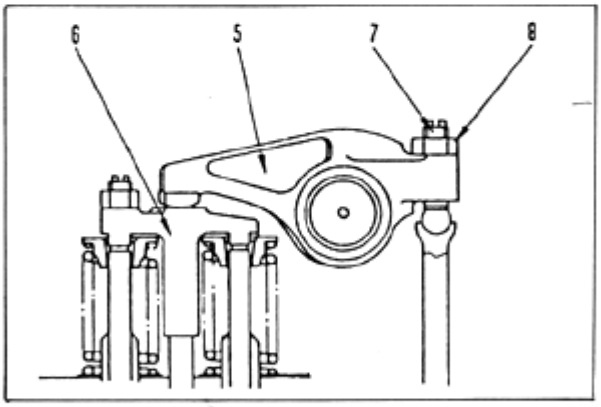
Method of adjusting valve clearance

1. Remove the cylinder head cover.
2. Rotate the crankshaft in the normal direction to set No.1 cylinder at compression top dead center, and align pointer (3) with the 1.6 TOP mark on vibration damper (2). When rotating, check the movement of the intake valve of No.6 cylinder.
   - ★ When No. 1 cylinder is near compression top dead center, the No.6 intake valve moves (is open).

★ Valve arrangement

Cylinder No.	1	2	3	4	5	6
Exhaust valve	●	○	●	○	●	○
Intake valve	●	●	○	●	○	○

3. Adjust the clearance of the valves marked ● in the valve arrangement chart.
4. Next, rotate crankshaft one turn in the normal direction and adjust the valve clearance of the remaining valves marked ○.



- ★ To adjust the valve clearance loosen locknut (8) of adjustment screw (7), insert feeler gauge **A** between crosshead (6) and rocker arm (5), and turn the adjustment screw until the clearance is a sliding fit.
  - ★ Valve clearance (cold, warm)

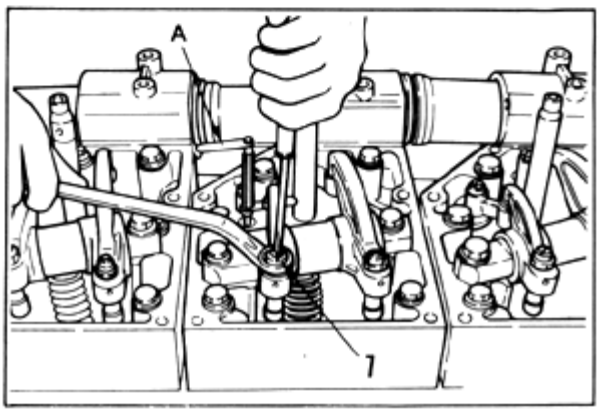
Unit: mm

Intake valve	Exhaust valve
0.4	1.0

5. Tighten the locknut to hold the adjustment screw in position.

kgm Locknut: 6.9 ± 1 kgm

- ★ It is also possible to turn the crankshaft 120° each time and adjust the intake and exhaust valves of each cylinder according to the firing order.
  - ● Firing order: 1-5-3-6-2-4
- ★ After tightening the locknut, check the clearance again.



MEASURING COMPRESSION PRESSURE

Method of measuring compression pressure

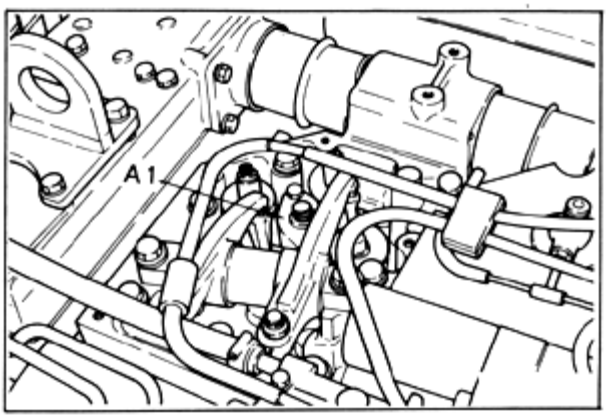
When measuring the compression pressure, be careful not to touch the exhaust manifold or muffler, or to get caught in rotating parts.

★ Measure the compression pressure with the engine warmed up (oil temperature: 40-60°C)

1. Adjust valve clearance.
   For details, see 12 ADJUSTING VALVE CLEARANCE.
2. Remove the nozzle holder assembly of the cylinder to be measured.
   ★ Be careful not to let any dirt or dust get in.

3. Install adapter **A1** in the mount of the nozzle holder assembly of the cylinder to be measured, and tighten to the specified torque.

   kgm Torque: 2.75 ± 0.25 kgm



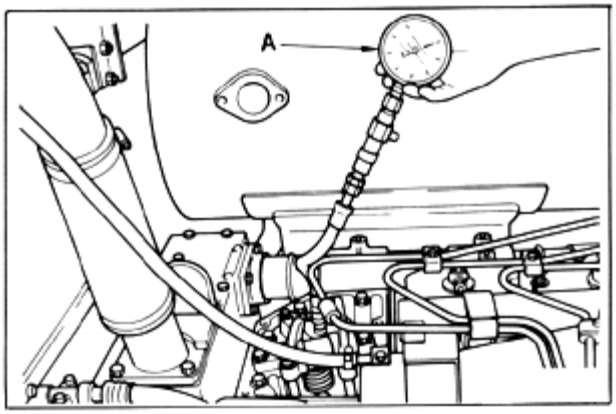
4. Connect compressor gauge **A** to the adapter.

5. Place the fuel control lever in the NO INJECTION position. Crank the engine with the starting motor and measure the compression pressure.

   If the fuel control lever is not placed in the NO INJECTION position, the fuel will spurt out.

   ★ If the adapter mount is coated with a small amount of oil, it will reduce the leakage.
   ★ For details of the standard value for the compression pressure, see TABLE OF VALUES FOR TESTING, ADJUSTING AND TROUBLESHOOTING .

   kgm Torque: 2.25 ± 0.25 kgm



FUEL SYSTEM

TESTING AND ADJUSTING FUEL INJECTION TIMING

There are the following methods of testing and adjusting the fuel injection timing of the injection pump.

- Aligning match mark when assembling the injection pump to the original engine without repair.
- Delivery valve method when assembling the injection pump that has been repaired or replaced.

★ When using the delivery valve method, always replace the copper gasket and O-ring of the delivery valve with new parts. Prepare these parts before starting the operation.

★ Set the No. 1 cylinder at the compression top dead center, then test and adjust.

For details, see ADJUSTING VALVE CLEARANCE

- **Testing and adjusting by aligning match mark (flange type)**

1. Turn the crankshaft back approx. 45° from No.1 cylinder TOP.
2. Rotate the crankshaft slowly in the normal direction to align pointer (with the injection timing line on crankshaft damper (1).
3. Check that line **a** at the fuel injection pump end and line **b** at the drive housing end are aligned.
   - ★ If the lines are not aligned adjust at the oblong hole of the flange.

     Bolt nut: 6.75 ± 0.75 kgm

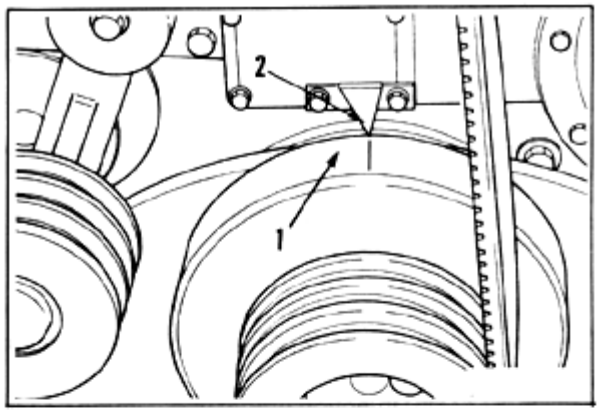
- **Testing and adjusting by aligning match mark (laminated coupling type)**

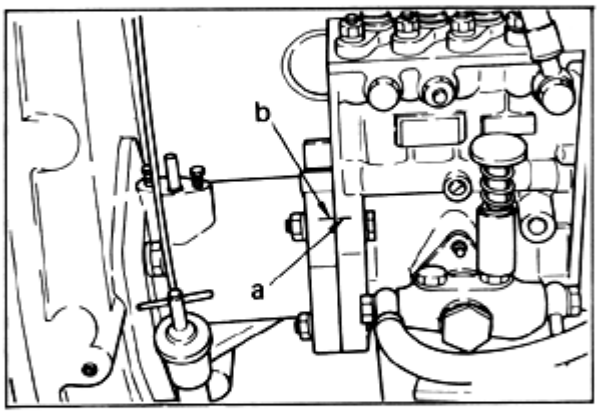
1. Follow the same procedure as for steps 1 and 2 for the flange type.
2. Check that the lines on the coupling and bearing cover of the fuel injection pump are aligned.
   - ★ If the lines are not aligned adjust at the oblong hole of the coupling.

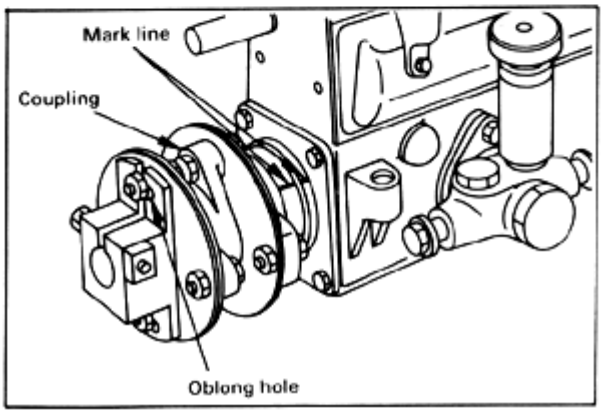
     Bolt nut: Width across flats of Tightening torque for

Injection pump type	nut for coupling oblong hole	bolt of oblong hole kgm
Bosch PE-P, PE-PD	19	9.0± 0.5
Bosch PE-ZWx	21	7.75± 0.25
Bosch PE-ZWy	21	16.0± 1.0

* 6162-73-1653 and 6162-73-1682 are the injection pump only







- **Testing fuel injection timing by delivery valve method**

★ Prepare new parts for the copper gasket and O-ring of the delivery valve before starting the operation.

1. Disconnect fuel injection pipe (1) of the No.1 cylinder.
2. Remove delivery valve holder (2), take out delivery valve (3) and spring (4), then install delivery valve holder (2) again.
3. Place the fuel control lever at the FULL position.
   ★ For injection pumps with a stop lever set to the OPERATION position.
4. Turn the crankshaft back 40-50° from top dead center.
5. Operate the feed pump and rotate the crankshaft slowly in the normal direction. Check the point where the fuel stops flowing from delivery valve holder (2).
6. Check that the fuel injection timing line on crankshaft pulley (5) and pointer (6) are aligned at the point where the fuel stops flowing.
   ★ BEYOND injection timing line: Timing RETARDED
   ★ BEFORE injection timing line: Timing ADVANCED

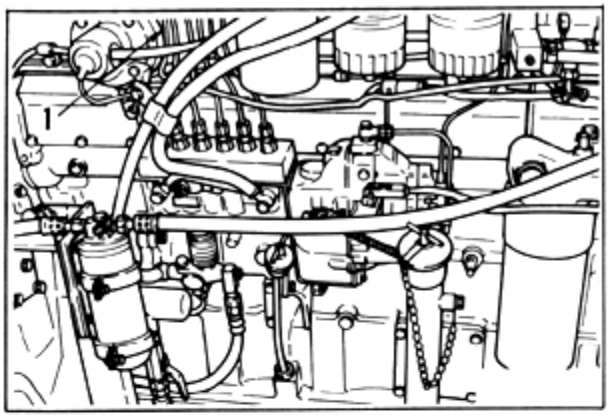
★ If the test shows that the fuel injection timing is incorrect, adjust at the oblong hole of the flange portion or at the oblong hole at the laminated coupling.

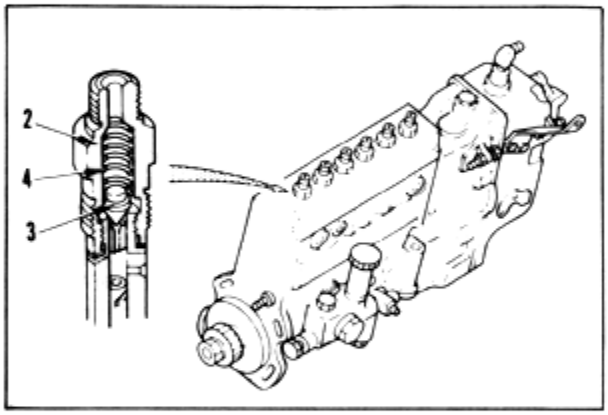
7. Remove delivery valve holder (2), assemble delivery valve (3) and spring (4), then install delivery valve holder (2) again.
   ★ When assembling again, wash with fuel and be careful not to let any dirt dust stick to any parts.
   ★ Always replace the copper gasket and O-ring of the delivery valve with new parts.

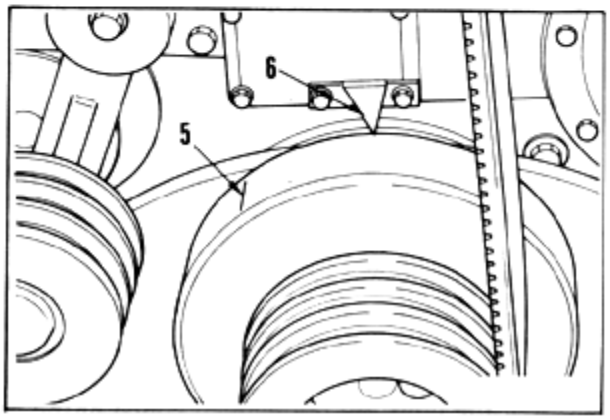
   kgm Delivery vavle holder: 11.5 ± 0.5 kgm
   Note: 14.0 ± 1.0 kgm for the EP11 injection pump on theBWD600

8. Connect fuel injection pipe (1).

   kgm Sleeve nu: 2.2 ± 0.2 kgm







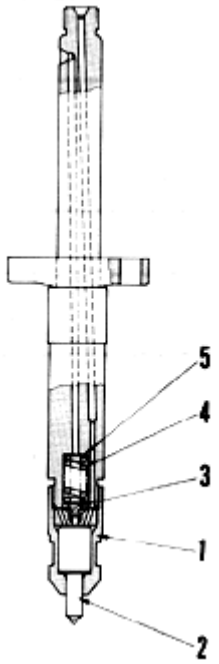
ADJUSTING FUEL INJECTION PRESSURE (VAVLE CRACKING PRESSURE)

1. Remove retaining cap (1).
2. Remove nozzle (2), spring seat (3), and zozzle spring (4).

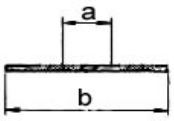
3. Adjust the injection pressure (valve cracking pressure) by adjusting shim thickness (5).
   ★ Injection pressure adjusted per 0.1 mm shim Thickness: Approx. 15kg/cm²

   kgm Retaining cap: 9 ± 1 kgm

4. After adjusting the thickness of shims, check the fuel injection pressure using nozzle tester.



DATA FOR INJECTION PRESSURE ADJUSTMENT SHIMS

Engine model	Shim contour	Shim thickness (Range)	Shim thickness (Interval)
BS6D170-1 BSA6D170-B-1	 a = 4.5 mm b = 11.5 mm	0.50 - 1.54 mm	0.02 mm

Part No.	Thickness (mm)	Part No.	Thickness (mm)
51Z7182481	0.50	51Z7182554	0.78
51Z7182498	0.54	51Z7182562	0.82
51Z7182505	0.58	51Z7182579	0.86
51Z7182513	0.62	51Z7182587	0.90
51Z7182521	0.66	51Z7182595	0.94
51Z7182538	0.70	51Z7182602	0.98
51Z7182546	0.74	51Z7182619	1.00

Pump Assembly Number

51Z7183153 (106692-4622)

( ): Manufacturer's part No.

Injection Pump Type	Pump Manufacturer
PES-6PD	DIESEL KIKI

Applicable Machine		Applicable Engine	
Model	Serial No.	Model	Serial No.
BD155A-1		BS6D170-1	

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	2.4 ± 0.05
Delivery valve Retraction volume mm^3/st	90

Engine specification

Rated horsepower	HP/rpm	320/2,000
Maximum torque	kgm/rpm	144/1,400
High idling	rpm	2,150 to 2,250
Low idling	rpm	600 to 700

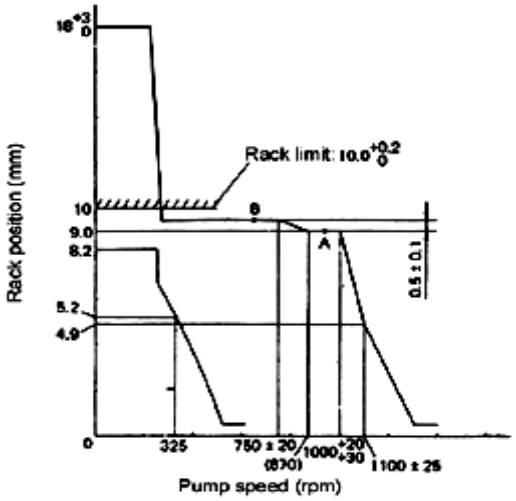
Pump tester capacity for Service standard	Motor 7.5 kW

Calibration Standard

Conditions		Service standard	Manufacture standard
• **Service standard** indicates data using calibration test parts • **Manufacture standard** is data for factory test .	Nozzle part no.	(105780-0000)	51Z7180601(105015-5210)
	Nozzle holder part no.	(105780-2090)	51Z7180586 (105041-7020)
	Injection pipe (O/D × I/D × length) mm	8 × 3 × 600	8 × 2.4 × 1,400
	Test oil	ASTM D975 No. 2 diesel fuel or equivalent	
	Oil temperature ℃	43 to 47	
	Nozzle opening pressure kg/cm^2	175	255
	Transfer pump pressure kg/cm^2	1.6	1.6

Injection volume	Rack point (mm)	Rack Position (rpm)	Pump Speed Basis	Service standard (cc/100 st) Basis	Allowance	Maximum variance between cylinder	Manufacture standard (cc/100st) Basis	Allowance	Maximum variance between cylinder
• Rack positions B to E are the reference volume when adjusting the injection volume. • Marks ★ are average volumes.	Basic point	9.0	1000	24.58	Each cylinder 23.88 to 25.28		20.60	Each cyl.	
	B	9.5	700	25.27	★ 24.77 to 25.77		23.00	★	
	C	5.2	325	2.77	★ 2.7 to 3.27	± 0.277	35.00	★	
	D				★			★	
	E				★			★	

Governor performance (325 - 1000 rpm)



Pump Assembly Number

51Z7183089 (106692-4970)

( ): Manufacturer's part No.

Injection Pump Type	Pump Manufacturer
PES-6PD	ZEXEL

Applicable Machine		Applicable Engine	
Model	Serial No.	Model	Serial No.
BD355A-3		BSA6D170-1	

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	2.4 ± 0.05
Delivery valve retraction volume mm^3/st	90

Engine specification

Rated horsepower	HP/rpm	410/2,000
Maximum torque	kgm/rpm	176/1,400
High idling	rpm	2,150 to 2,250
Low idling	rpm	600 to 700

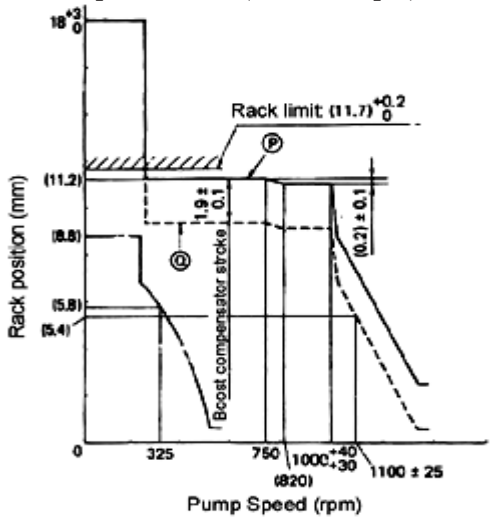
Pump tester capacity for Service standard	Motor 7.5 kW

Calibration Standard

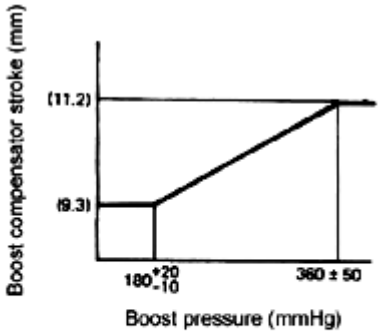
Conditions		Service standard	Manufacture standard
• **Service standard** indicates data using calibration test parts • **Manufacture standard** is data for factory test.	Nozzle part no.	(105780-0000)	51Z7180601(105015-5210)
	Nozzle holder part no.	(105780-2090)	51Z7180586 (105041-7020)
	Injection pipe (O/D × I/D × length) mm	8 × 3 × 600	8 × 2.4 × 1,450
	Test oil	ASTM D975 No. 2 diesel fuel or equivalent	
	Oil temperature ℃	43 to 47	
	Nozzle opening pressure kg/cm^2	175	225
	Transfer pump pressure kg/cm^2	1.6	1.6

Injection volume	Rack point	Rack Position (mm)	Pump Speed (rpm)	Service standard (cc/100 st) Basis	Allowance	Maximum variance between cylinder	Manufactur standard (cc/100st) Basis	Allowance	Maximum variance between cylinder
• Rack positions B to E are the reference volume when adjusting the injection volume. • Marks ★ are average volumes.	Basic point	(11.0)	1000	29.00	Each cylinder 28.50 to 29.50		26.00	Each cyl.	
	B	(11.2)	700	30.70	★ 30.20 to 31.20		28.00	★	
	C	(5.8)	325	2.75	★ 2..25 to 3.25	± 0.275	35.00	★	
	D				★			★	
	E				★			★	

Governor performance (325 - 1000 rpm)



Boost compensator performance (400 rpm)



Line Ⓟ : At boost pressure 460mmHg or more
Line Ⓠ : At boost pressure 0mmHg

Pump Assembly Number

52Z7180372 (106682-4560)

( ): Manufacturer's part No.

Injection Pump Type	Pump manufacturer
PE-6P	DIESEL KIKI

Applicable Machine		Applicable Engine	
Model	Serial No.	Model	Serial No.
BE1000-1		BSA6D170-1	

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	3.2 ± 0.05
Delivery valve retraction volume mm^3/st	120

Engine specification

Rated horsepower	HP/rpm	542/1,700
Maximum torque	kgm/rpm	260/1,300
High idling	rpm	1,800 to 1,900
Low idling	rpm	650 to 700

Pump tester capacity for Service standard	Motor 7.5 kW

Calibration Standard

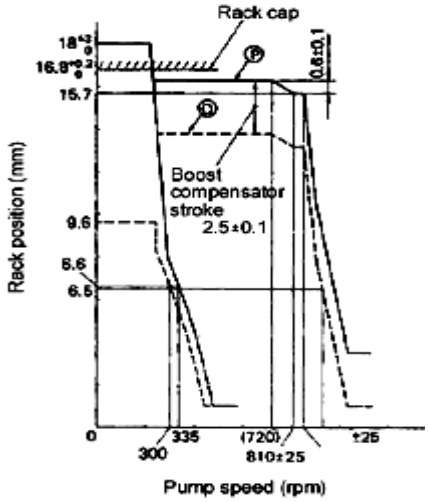
Conditions		Service standard	Manufacture standard
• **Service standard** indicates data using calibration test parts (Nozzle, Nozzle holder and injection pipe) • **Manufacture standard** is data using factory test parts (For reference)	Nozzle part no.	(105780-0050)	52Z7180267 (105015-6700)
	Nozzle holder part no.	(105780-2090)	52Z7180259 (105041-7060)
	Injection pipe (O/D × I/D × length) mm	8 × 4 × 1000	8 × 2.4 × 1,450
	Test oil	ASTM D975 No. 2 diesel fuel or equivalent	
	Oil temperature ℃	43 to 47	
	Nozzle opening pressure kg/cm^2	175	265
	Transfer pump pressure kg/cm^2	1.6	1.6

Injection volume

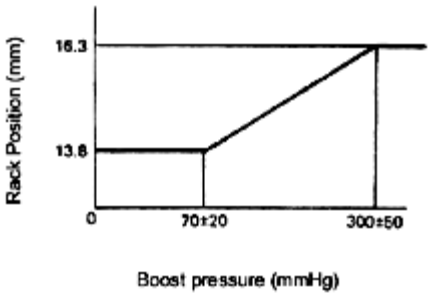
- Rack positions B to E are the reference volume when adjusting the injection volume.
- Marks ★ are average volumes.

Rack point	Rack Position (mm)	Pump Speed (rmp)	**Service standard** (cc/100 st) Basis	Allowance	Maximum variance between cylinder	**Manufacture standard** (cc/100st) Basi	Allowance	Maximum variance between cylinder
Basic point	15.7	850	40.15	Each cylinder 39.95 to 40.35	± 1.204	35.5	Each cyl.	
B	Approx.6.6	335	3.26	★ 2.76 to 3.76	± 0.489	3.5	★	
C				★			★	
D				★			★	
E				★			★	

Governor performance (335 - 850 rpm)



Boost compensator performance (500 rpm)



Line Ⓟ : At boost pressure 300 mmHg or more
Line Ⓠ : At boost pressure 0 mmHg

Pump Assembly Number

53Z 710 0024

Injection Pump Type	Pump manufacturer
NP-PE6 ZW	ZEXEL

Applicable Machine	Applicable Engine
BH60	BSA6D170A-1

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	-
Delivery valve retraction volume mm^3/st	-

Engine specification (reference only)

Rated horsepower	kW/rpm	522/2100
Maximum torque	Nm/rpm	2785/1400
High idling	rpm	2330 to 2400
Low idling	rpm	900 to 950

Calibration Standard

Conditions		Manufacture standard	Service standard
• **Service standard** indicates data using calibration test parts (Nozzle, Nozzle holder and injection pipe)	Nozzle part no.	-	-
	Nozzle holder part no.	-	-
	Injection pipe (O/D × I/D × length) mm	8 × 2.4 × 1400	8 × 4 × 1400
	Test Fuel	ASTM D975 No. 2 diesel fuel	
• **Manufacture standard** is data using factory test parts (For reference)	Fuel temperature ℃	40 to 45	
	Nozzle opening pressure kg/cm^2	300	175
	Transfer pump pressure kg/cm^2	1.6	1.6

Injection volume		Rack Position (mm)	Pump Speed (rmp)	**Manufacture standard** (cc/100st) Basis (Each cylinder) ★	Allowance (Each cylinder) ★	Maximum variance between cylinder	**Service standard** (cc/100 st) Basi (Each cylinder) ★	Allowance (Each cylinder) ★	Maximum variance between cylinder
★ Average of 6 cylinders		-	1050	36.5	36.5 to 37.0	≤1.5	28	27.5 - 28.5	≤1.1
		-	465	3.5	3.0 to 4.0	≤0.5	6	5.0 - 7.0	≤0.5
		-	700	40.8	39.8 to 49.8	≤1.5	30	29.5 - 30.5	≤1.1

$: READINGS ARE WITHOUT BOOST COMPENSATION

Pump Assembly Number

53Z 710 2041

Injection Pump Type	Pump manufacturer
NP-PE6 ZW	ZEXEL

Applicable Machine	Applicable Engine
BH70	BSA6D170A-1

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	-
Delivery valve retraction volume mm³/st	-

Engine specification (reference only)

Rated horsepower	kW/rpm	551/2100
Maximum torque	Nm/rpm	3010/1400
High idling	rpm	2330 to 2400
Low idling	rpm	900 to 950

Calibration Standard

Conditions		Manufacture standard	Service standard
• **Service standard** indicates data using calibration test parts (Nozzle, Nozzle holder and injection pipe) • **Manufacture standard** is data using factory test parts (For reference)	Nozzle part no.	-	-
	Nozzle holder part no.	-	-
	Injection pipe (O/D × I/D × length) mm	8 × 2.4 × 1400	8 × 4 × 1400
	Test Fuel	ASTM D975 No. 2 diesel fuel	
	Fuel temperature ℃	40 to 45	
	Nozzle opening pressure kg/cm²	300	175
	Transfer pump pressure kg/cm²	1.6	1.6

Injection volume		Rack Position (mm)	Pump Speed (rmp)	**Manufacture standard** (cc/100st)			**Service standard** (cc/100 st)		
				Basis (Each cylinder) ★	Allowance	Maximum variance between cylinder	Basi (Each cylinder) ★	Allowance	Maximum variance between cylinder
★ Average of 6 cylinders		-	1050	38.5	37.9 to 38.9	≤1.5	29.6	29.1 - 30.1	≤1.1
		-	465	3.5	3.0 to 4.0	≤0.5	6	5.0 - 7.0	≤0.5
		-	700	43.9	43.4 to 44.4	≤1.5	33	32.5 - 33.5	≤1.1

$: READINGS ARE WITHOUT BOOST COMPENSATION

Pump Assembly Number

53Z 710 2041

Injection Pump Type	Pump manufacturer
NP-PE6 ZW	ZEXEL

Applicable Machine	Applicable Engine
210M	BSA6D170A-1

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	-
Delivery valve retraction volume mm^3/st	-

Engine specification (reference only)

Rated horsepower	kW/rpm	501/2100
Maximum torque	Nm/rpm	2618/1400
High idling	rpm	2330 to 2400
Low idling	rpm	900 to 950

Calibration Standard

Conditions		Manufacture standard	Service standard
• **Service standard** indicates data using calibration test parts (Nozzle, Nozzle holder and injection pipe)	Nozzle part no.	-	-
	Nozzle holder part no.	-	-
	Injection pipe (O/D × I/D × length) mm	8 × 2.4 × 1400	8 × 4 × 1400
	Test Fuel	ASTM D975 No. 2 diesel fuel	
• **Manufacture standard** is data using factory test parts (For reference)	Fuel temperature ℃	40 to 45	
	Nozzle opening pressure kg/cm^2	300	175
	Transfer pump pressure kg/cm^2	1.6	1.6

Injection volume		Rack Position (mm)	Pump Speed (rmp)	**Manufacture standard** (cc/100st)			**Service standard** (cc/100 st)		
				Basis	Allowance (Each cylinder) ★	Maximum variance between cylinder	Basi	Allowance (Each cylinder) ★	Maximum variance between cylinder
★ Average of 6 cylinders		-	1050	35.5	34.5 to 35.5	≤1.5	27	26.5 - 27.5	≤1.1
		-	465	3.5	3.0 to 4.0	≤0.5	6	5.0 - 7.0	≤0.5
		-	700	39.0	38.5 to 39.5	≤1.5	29	28.5 - 29.5	≤1.1

$: READINGS ARE WITHOUT BOOST COMPENSATION

Pump Assembly Number

54Z 710 0054

Injection Pump Type	Pump manufacturer
PE-ZWX	ZEXEL

Applicable Machine	Applicable Engine
BDG500	BSA6D170AG-1

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	-
Delivery valve retraction volume mm^3/st	-

Engine specification (reference only)

Rated horsepower	kW/rpm	426/1500
Maximum torque	Nm/rpm	--
High idling	rpm	1560 Max.
Low idling	rpm	975 to 1025

Calibration Standard

Conditions		Manufacture standard	Service standard
• **Service standard** indicates data using calibration test parts (Nozzle, Nozzle holder and injection pipe) • **Manufacture standard** is data using factory test parts (For reference)	Nozzle part no.	-	-
	Nozzle holder part no.	-	-
	Injection pipe (O/D × I/D × length) mm	8 × 2.4 × 1400	8 × 4 × 1400
	Test Fuel	ASTM D975 No. 2 diesel fuel	
	Fuel temperature ℃	40 to 45	
	Nozzle opening pressure kg/cm^2	300	240
	Transfer pump pressure kg/cm^2	1.6	1.6

Injection volume		Rack Position (mm)	Pump Speed (rmp)	**Manufacture standard** (cc/100st)			**Service standard** (cc/100 st)		
				Basis (Each cylinder) ★	Allowance	Maximum variance between cylinder	Basi (Each cylinder) ★	Allowance	Maximum variance between cylinder
★ Average of 6 cylinders		-	750	40.5	39.5 to 41.5	≤1.5	27	26.5 - 27.5	≤1.1
		-	500	3.5	3.0 to 4.0	≤0.5	6	5.0 - 7.0	≤0.5

Pump Assembly Number

54Z 710 0054

Injection Pump Type	Pump manufacturer
PE-ZWX	ZEXEL

Applicable Machine	Applicable Engine
BDG550	BSA6D170AG-1

Injection Timing

Rotating direction	Counterclockwise viewed from drive end
Injection order	1 - 5 - 3 - 6 - 2 - 4
Injection interval	60° ± 30'
Plunger pre-stroke mm	-
Delivery valve retraction volume mm^3/st	-

Engine specification (reference only)

Rated horsepower	kW/rpm	468/1500
Maximum torque	Nm/rpm	--
High idling	rpm	1560 Max.
Low idling	rpm	975 to 1025

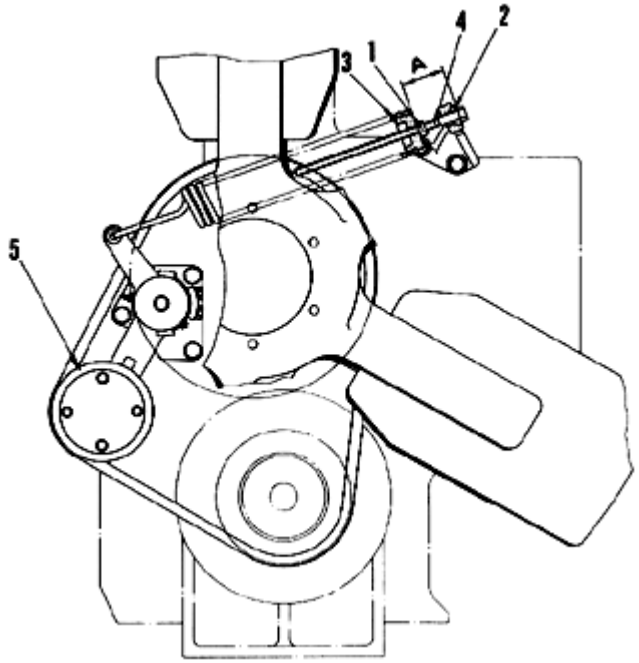
Calibration Standard

Conditions		Manufacture standard	Service standard
• **Service standard** indicates data using calibration test parts (Nozzle, Nozzle holder and injection pipe) • **Manufacture standard** is data using factory test parts (For reference)	Nozzle part no.	-	-
	Nozzle holder part no.	-	-
	Injection pipe (O/D × I/D × length) mm	8 × 2.4 × 1400	8 × 4 × 1400
	Test Fuel	ASTM D975 No. 2 diesel fuel	
	Fuel temperature ℃	40 to 45	
	Nozzle opening pressure kg/cm^2	300	240
	Transfer pump pressure kg/cm^2	1.6	1.6

Injection volume		Rack Position (mm)	Pump Speed (rmp)	**Manufacture standard** (cc/100st)			**Service standard** (cc/100 st)		
				Basis	Allowance (Each cylinder) ★	Maximum variance between cylinder	Basi	Allowance (Each cylinder) ★	Maximum variance between cylinder
★ Average of 6 cylinders		-	750	44	043 to 45	≤1.5	27	26.5 - 27.5	≤1.1
		-	500	3.5	3.0 to 4.0	≤0.5	6	5.0 - 7.0	≤0.5

COOLING SYSTEM

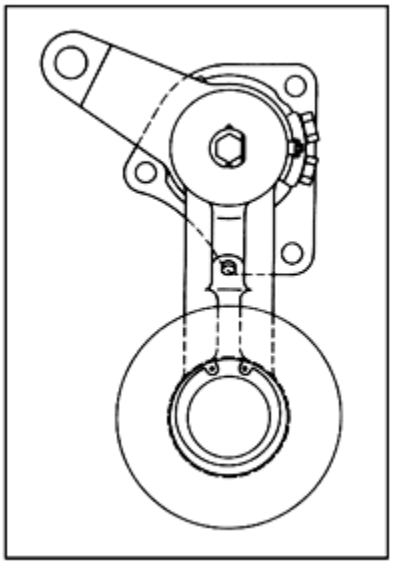
FAN BELT TENSION



1. Adjusting nut
2. Washer
3. Tension spring
4. Adjustment bolt
5. Tension pulley

A. Protrusion of adjustment bolt

BD275A-2

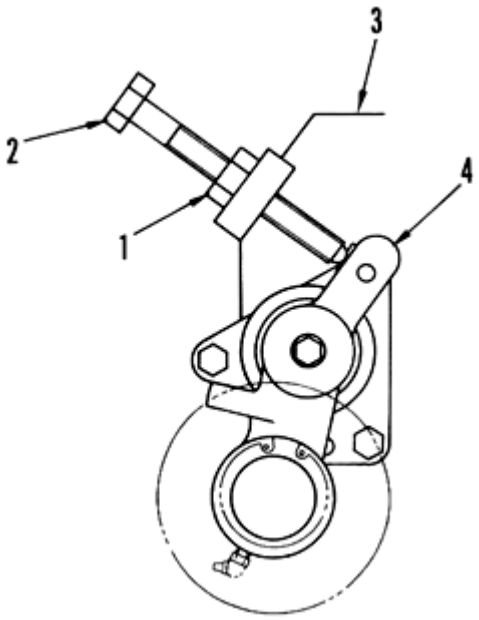


Q area

Unit: mm

Engine model	Applicable machine	Dimension A
BS6D170-1	BD155	72 5
	BD355	
BSA6D170-1	BE1000	60 5

REPLACING FAN BELT AND ADJUSTING AUTO TENSIONER



- **Replacing**

1. Loosen locknut (1) and turn back adjustment screw (2) as far as bracket (3).

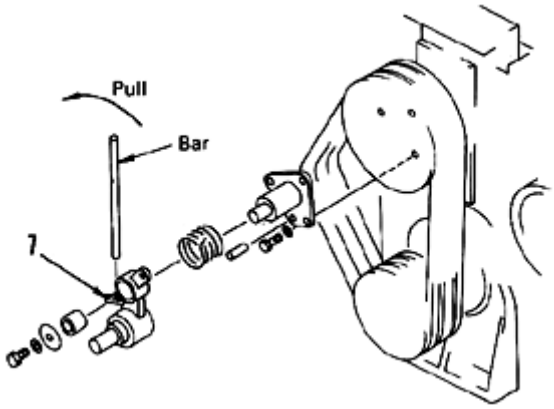
2. Insert a bar with a length of approx. 50 cm in the hole (ø18) in bracket (7), then pull strongly to the front and hold in position.

3. The spring will extend and the tension pulley will move to the inside. Remove the old belts and replace it with new bolts.
   ★ Replace the V-belts in a set (3 belts).

- **Adjusting**

1. Tighten adjustment screw (2), and when the tip of adjustment screw (2) comes into contact with tension pulley lever (4), tighten adjustment screw (2) a further half turn, then lock it in position with locknut (1).

   kgm Locknut : 29.5 ± 2 kgm



★ If a gap appears between tension pulley lever (4) and the tip of adjustment screw (2) during operation, adjust in the same way.

★ If the fan belt screeches, adjust in the same way.

PERFORMANCE TEST

RUN-IN STANDARD

Engine model	Applicable machine	Item		1	2	3	4	5	6
BS6D170-1	BD155	Running time	(min	3	6	3	3	10	5
		Engine speed	(rpm)	650	1,000	1,200	1,200	1,500	2,000
		Load 716 mm	(kg)	0	40	90	140	210	170
		895 mm	(kg)	0	32	72	112	168	176
		1,023 mm	(kg)	0	28	63	98	147	119
		Horsepower	(HP)	0	39.4	106.4	165.6	310.6	335.2
	BD355	Running time	(min)	3	6	3	3	10	5
		Engine speed	(rpm)	650	1,000	1,200	1,200	1,500	2,000
		Load 716 mm	(kg)	0	40	90	140	210	220
		895 mm	(kg)	0	32	72	112	168	176
		1,023 mm	(kg)	0	28	63	98	147	154
		Horsepower	(HP)	0	39.4	106.4	165.6	310.6	433.8
BSA6D170-1	BE1000-1	Running time	(min)	3	6	3	3	10	5
		Engine speed	(rpm)	650 ± 25	1,000	1,200	1,200	1,500	1,700
		Load 716 mm	(kg)	0	40	90	140	210	330
		895 mm	(kg)	0	-	-	-	-	-
		1,023 mm	(kg)	0	-	-	-	-	-
		Horsepower	(HP)	0	39.4	106.5	165.6	310.6	553.1

★ The values given for the output is the fan removed.
★ The load (dynamometer) is given for the case of the arm length is 17.6 mm, 895 mm or 1,023 mm.

RUN-IN STANDARD

★ Loads are given for the case of dynamometer with 716mm arm length.
★ The values shown below are at standard condition and without fan.

Engine model	Applicable machine	Test parameter		Order					
				1	2	3	4	5	6
BSA6D170A-1	BH60	Running time	(min.)	5	10	10	10	20	5
		Engine speed	(rpm)	LI	1050	1300	1600	1900	2100
		Load 716 mm	(kg)	-	43	84	169	253	327
		Out put	(kW)	-	33	80	199	354	506
	BH70	Running time	(min.)	5	10	10	10	20	5
		Engine speed	(rpm)	LI	1050	1300	1600	1900	2100
		Load 716 mm	(kg)	-	44	90	178	268	346
		Out put	(kW)	-	34	86	209	374	534
	210M	Running time	(min.)	5	10	10	10	20	5
		Engine speed	(rpm)	LI	1050	1300	1600	1900	2100
		Load 716 mm	(kg)	-	43	81	162	242	313
		Out put	(kW)	-	33	78	191	338	484
BSA6D170AG-1	BDG500	Running time	(min.)	5	5	10	10	15	15
		Engine speed	(rpm)	1000	1100	1200	1300	1400	1500
		Load 716 mm	(kg)	-	78	155	233	310	388
		Out put	(kW)	-	63	137	222	319	428
	BDG550	Running time	(min.)	5	5	10	10	15	15
		Engine speed	(rpm)	1000	1100	1200	1300	1400	1500
		Load 716 mm	(kg)	-	86	172	258	344	430
		Out put	(kW)	-	70	152	246	354	474

PERFORMANCE TEST CRITERIA

Engine model	Applicable machine	Test item	Specified value (fully equipped)	Engine speed (rpm)	Dynamometer (kg)		
					Arm length 716 mm	Arm length 895 mm	Arm length 1,023 mm
BS6D170-1	BD155	Flywheel horsepower	320 HP/ 2,000 rpm	2,000 ± 5	168.0 - 178.0	134.4 -142.4	117.6 - 124.6
		Max. torque	144 kgm/ 1,400 rpm	1,400 ± 100	205.3 - 217.8	164.2 - 174.2	143.7 - 152.5
		High idling speed	2,200 ± 50 rpm	2,150 - 2,250	0	0	0
		Low idling speed	650 ± 50 rpm	600 - 700	0	0	0
	BD355	Flywheel horsepower	410 HP/ 2,000 rpm	2,000 ± 5	220.0 - 232.0	176.0 -185.6	154.0 - 162.4
		Max. torque	176 kgm/ 1,400 rpm	1,400 ± 100	252.8 - 267.5	202.2 - 214.0	177.0 - 189.2
		High idling speed	2,200 ± 50 rpm	2,150 - 2,250	0	0	0
		Low idling speed	650 ± 50 rpm	600 - 700	0	0	0
BSA6D170–1	BE1000	Flywheel horsepower	542 HP/ 1,700 rpm	1,700 ± 5	329.0 - 348.0	263.2 -278.4	230.3 - 243.6
		Max. torque	260 kgm/ 1,300 rpm	1,300 ± 100	361.0 - 382.0	288.8 - 305.6	252.7 - 267.4
		High idling speed	1,850 ± 50 rpm	1,850 ± 50	0	0	0
		Low idling speed	675 ± 25 rpm	675 ± 25	0	0	0

- ★ The values in the table are indicated at standard conditions (Atmospheric temperature 25°C, atmospheric pressure 750 mm Hg).
- ★ The values given for dynamometer loads the output and torque are with the fan removed, so they differ from those of the specification.
- ★ Values are standardized under the following conditions: Muffler; air cleaner installed; alternator idling; and air compressor (if installed) open.
- ★ Dynamometer loads are given for the case of the arm length is 716 mm.
- ★ Fuel used: ASTM D975 No. 1 or No. 2 diesel fuel.
- ★ Lubrication oil used: CLASS - CO SAE30.
- ★ Exhaust temperature column t: (Suction temperature - 25°C)

Output (HP)	Torque (kgm)	Fuel consumtion (sec /500 cc)	Coolant temperature (°C)	Lubrication oil temperature (°C)	Lubrication oil pressure (kg/cm²)	Exhaust temperature (°C) t = Intake temp. - 20°C
331.3 - 351.0	-	Min. 23.3	70 - 90	80 - 110	3.0 - 5.0	600 + 3t
-	147.0 - 156.0	-	70 - 90	80 - 110	-	650 + 3t
0	0	0	70 - 90	80 - 110	-	-
0	0	0	70 - 90	80 - 110	-	-
433.8 - 457.5	-	Min. 19.2	70 - 90	80 - 110	3.0 - 5.0	600 + 3t
-	181.0 - 191.5	-	70 - 90	80 - 110	-	650 + 3t
0	0	0	70 - 90	80 - 110	-	-
0	0	0	70 - 90	80 - 110	-	-
559.0 - 592.0	-	Min. 16.3	70 - 90	80 - 110	3.5 - 5.0	Max. 700 + 3t
-	258.4 - 273.5	-	70 - 90	80 - 110	2.0 - 4.0	Max. 700 + 3t
0	0	0	70 - 90	80 - 110	3.5 - 5.0	-
0	0	0	70 - 90	Min. 80	Min. 1.5	-

PERFORMANCE TEST CRITERIA

Engine model	Applicable machine	Test item	Specified value (with fan)	Engine speed (rpm)	Dynamometer (Kg)
BSA6D170A-1	BH60	Flywheel horsepower	504 kW/2100 rpm	2095 ~ 2105	328 ~ 348
		Max. torque	2750 Nm/1400/rpm	1300 ~ 1500	348 ~ 409
		High idling speed	2365 ± 35 rpm	2330 ~ 2400	0
		Low idling speed	925 ± 25 rpm	900 - 950	0
	BH70	Flywheel horsepower	533 kW/2100 rpm	2095 ~ 2105	346 ~ 368
		Max. torque	2975 Nm/1400/rpm	1300 ~ 1500	416 ~ 442
		High idling speed	2365 ± 35 rpm	2330 ~ 2400	0
		Low idling speed	925 ± 25 rpm	900 - 950	0
	210M	Flywheel horsepower	483 kW/2100 rpm	2095 ~ 2105	315 ~ 334
		Max. torque	2618 Nm/1400/rpm	1300 ~ 1500	366 ~ 389
		High idling speed	2365 ± 35 rpm	2330 ~ 2400	0
		Low idling speed	925 ± 25 rpm	900 - 950	0
BSA6D170AG-1	BDG500	Flywheel horsepower	426kW/1500 rpm	1500	315 ~ 334
		High idling speed	1560 ± 15 rpm	1555 ~ 1565	0
		Low idling speed	1000 ± 25 rpm	975 - 1025	0
	BDG550	Flywheel horsepower	468kW/1500 rpm	1500	315 ~ 334
		High idling speed	1560 ± 15 rpm	1555 ~ 1565	0
		Low idling speed	1000 ± 25 rpm	975 - 1025	0

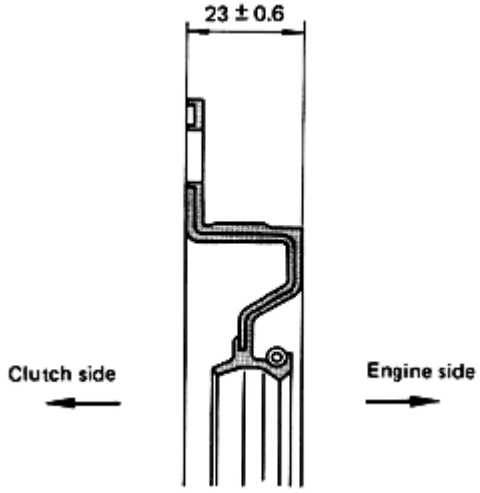
- ★ The values in the table are indicated at standard conditions (Atmospheric temperature 25°C, atmospheric pressure 743 mm Hg).
- ★ The values given for the dynamometer loads, output and torque are with the fan removed, so they differ from those of the specification.
- ★ Values are standardized under the following conditions: Muffler and air cleaner installed; alternator and compressor (if installed) under no load.
- ★ Dynamometer loads are given for the case of the arm length is 716 mm.
- ★ Fuel used: ASTM D975 No. 2 diesel fuel.
- ★ Lubrication oil used: CLASS - CD SAE30.

Output (kW)	Torque (Nm)	Fuel consumtion (sec /500 cc)	Coolant temperature (°C)	Lubrication oil temperature (°C)	Lubrication oil pressure (kg/cm²)	Exhaust temperature (turbo inlet) (°C)
506 ~ 538	-	Min. 12	75 - 90	80 - 110	3.0 ~ 5.0	Max. 680
-	2700 ~ 2870	-	75 - 90	80 - 110	-	Max. 700
0	0	-	75 - 90	80 - 110	-	-
0	0	-	75 - 90	80 - 110	Min 1.5	-
534 ~ 538	-	Min. 11	75 - 90	80 - 110	3.0 ~ 5.0	Max. 680
-	2920 ~ 3100	-	75 - 90	80 - 110	-	Max. 700
0	0	-	75 - 90	80 - 110	-	-
0	0	-	75 - 90	80 - 110	Min 1.5	-
486 ~ 516	-	Min. 13	75 - 90	80 - 110	3.0 ~ 5.0	Max. 680
-	2573 ~ 2733	-	75 - 90	80 - 110	-	Max. 700
0	0	-	75 - 90	80 - 110	-	-
0	0	-	75 - 90	80 - 110	Min 1.5	-
486 ~ 516	-	Min. 13	75 - 90	80 - 110	3.0 ~ 5.0	Max. 680
0	0	-	75 - 90	80 - 110	-	-
0	0	-	75 - 90	80 - 110	Min 1.5	-
486 ~ 516	-	Min. 13	75 - 90	80 - 110	3.0 ~ 5.0	Max. 680
0	0	-	75 - 90	80 - 110	-	-
0	0	-	75 - 90	80 - 110	Min 1.5	-

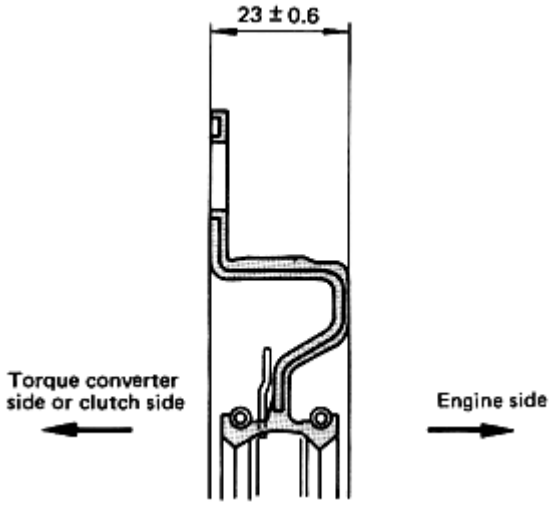
PRECAUTIONS WHEN OPERATING THE ENGINE INDEPENDENTLY

★ If the engine is operated independently on a bench with a double lip seal fitted, the lubricating conditions will differ from actual running conditions, resulting in possible damage to the seal lip.

1. When running-in the engine or subjecting it to a bench test, use the rear seal shown in the diagram at right on all models for the duration of testing.



2. After completing running-in or bench testing, fit the correct rear seal.



★ Precautions when fitting rear seal

1) A new rear seal is coated with grease. In the event that it becomes soiled, however, wipe it clean with a cloth and coat it with about 1.2 to 1.6 cc of G2-L1 (lithium grease).

2) Be careful not to damage the rear seal when fitting it.

TESTING AND ADJUSTING TOOL LIST

No.	Inspection and measuring item	Fault finding tool	Part No.	Remarks
1	Engine speed	Multi-tachometer	799-203-8000	Digital reading, pressure sensing type 60 to 20,000 rpm
2	Battery S.G	Battery, coolant tester	795-500-1001	1,100 to 1,300
3	Freezing temperature of cooling water			-5° C to -50° C
4	Water temperature, oil temperature, air intake temperature	Thermistor temperature gauge	790-101-6000	0 to 200° C
5	Exhaust temperature			0 to 1,000° C
6	Lubrication oil pressure	Engine pressure measuring kit	799-203-2002	0 to 10 kg/cm²
7	Fuel pressure			0 to 20 kg/cm²
8	Intake pressure, exhaust pressure			0 to 1,500 mmHg
9	Blow-by pressure			0 to 1,000 mmH_2O
10	Air intake resistance			- 1,000 to 0 mmH_2O
11	Compression pressure	Compression gauge kit	795-502-1203	0 to 70 kg/cm²
12	Blow-by pressure	Blow-by checker	799-201-1503	0 to 500 mmH_2O
13	Valve clearance	Feeler gauge	795-125-1340	0.4, 1.0 mm
14	Exhaust gas color	Handy smoke checker	799-201-9000	Dirtiness 0 to 70% with standard color (Dirtiness % × 1/10= Bosch scale)
15	Water and fuel content in oil	Engine oil checker	799-201-6000	Provided with 0.1and 0.2% water content standard samples.
16	Fuel injection pressure	Nozzle tester	Commercially available	0 to 300 kg/cm²
17	Fuel injection nozzle spray condition			
18	Coolant quality	Water quality tester	799-202-7001	pH, nitrite ion concentration
19	Pressure valve performance	Radiator cap tester	799-202-9001	0 to 2 kg/cm²
20	Leakage in cooling water system			
21	Radiator blockage (wind speed)	Anemometer (Air speed gauge)	799-202-2001	1 to 40 m/s
22	Engine cranking	Cranking kit	795-610-1000	DC24V with starting engine
		Barring device	6162-23-4820	For B6D170-1 series engine
23	Electrical circuits	Tester	Commercially available	Current, voltage, resistance

TESTING AND ADJUSTING DATA

Engine model				BS6D170-1			
Applicable machine model				BD155		BD355	
Classification	Item	Condition,etc	Unit	Standard	Tolerance	Standard	Tolerance
Performance	Engine speed	Highidling speed	rpm	2,150 - 2,250	2,150 - 2,250	2,150 - 2,250	2,150 - 2,250
		Low idling speed	rpm	600-700	600 - 700	600 - 700	600 - 700
	Necessary	0° C	rpm	Min. 100	-	Min. 100	-
	Starting speed	- 20° C (with starting aid)	rpm	Min. 100	-	Min. 100	-
Intake and exhaust system	Intake resistance	At all speed	mmH_2O	Max. 300	762	Max. 200	762
	Intake pressure	At rated output	mmHg				
	Exhaust pressure (Turbine inlet pressure)	At rated output	mmHg				
	Exhaust temperature (Turbine inlet temp.)	All speed (intake air temp.: 20° C)	° C	Max. 650	Max. 650	Max. 650	Max. 650
	Exhaust gas color	Quick acceleration (Low idling→High idling)	Bosch Scale	Max. 6.0 Max. 2.0	8.0 3.0	Max. 6.0 Max. 2.0	8.0 3.0
		At rated output					
		At high idling					
	Valve clearance (when engine is hot or cold.)	Intake valve	mm	0.4	-	0.4	-
		Exhaust valve	mm	1.0	-	1.0	-
Engine body	Compression Pressure (SAE30 oil)	Oil temperature: 40° C to 60° C (Engine speed)	Kg/cm² (rpm)	Min. 29 (210 - 250)	20 (210 - 250)	Min. 29 (210 - 250)	20 (210 - 250)
	Blow-by pressure (SAE30 oil)	At rated output Water temperature: Min. 70° C	mmH_2O	Max. 150	300	Max. 150	300
Lubrication system	Oil Pressure (Oil temperature: Min. 80° C)	At rated output SAE30 oil	Kg/cm²	3.0 - 5.0	2.1	3.0 - 5.0	2.1
		SAE10W oil	Kg/cm²				
		At low idling SAE30 oil	Kg/cm²	Min. 1.5	0.7	Min. 1.5	0.7
		SAE10W oil	Kg/cm²	Min. 1.0	0.7	Min. 1.0	0.7
	Oil temperature	All speed (oil in oil pan)	° C	80 - 110	120	80 - 110	120
	Oil consumption ratio	At continuous rated output (Ratio of fuel consumption)	%	Max. 0.5	1.0	Max. 0.5	1.0
Fuel system	Fuel injection pressure	Nozzle tester	Kg/cm²	255^{+13}_{+5}	230	255^{+13}_{+5}	230
	Fuel injection timing	B.T.D.C	degree	42 ± 1	42 ± 1	37° ± 1 (w/timer 8°)	37° ± 1 (w/timer 8°)
Cooling system	Radiator pressure valve	Opening pressure (Differential pressure)	Kg/cm²	0.75 ± 0.1	0.75 ± 0.1	0.75 ± 0.1	0.75 ± 0.1
	Fan speed	At rated engine speed	rpm	1,000 ± 25	1,000 ± 25	1,100 ± 25	1,100 ± 25
	Fan belt tension	Deflects when pushed with a force of 6 kg	mm	See page 12 - 011		See page 12 - 011	

★ The values given in the Testing and Adjusting data are NOT for adjustment of the output.
Do not use these values as a guide to change the setting of the fuel injection pump.

Engine model				BSA6D170-1	
Applicable machine model				BE1000	
Classification	Item	Condition,etc	Unit	Standard	Tolerance
Performance	Engine speed	Highidling speed	rpm	1,850 ± 50	1,850 ± 50
		Low idling speed	rpm	675 ± 25	675 ± 25
	Necessary	0° C	rpm	Min. 130	-
	Starting speed	- 20° C (with starting aid)	rpm	Min. 100	-
Intake and exhaust system	Intake resistance	At all speed	mmH_2O	Max. 300	762
	Intake pressure	At rated output	mmHg	Min. 1,000	900
	Exhaust pressure (Turbine inlet pressure)	At rated output	mmHg	Min. 900	810
	Exhaust temperature (Turbine inlet temp.)	All speed (intake air temp.: 20° C)	° C	Max. 650	Max. 700
	Exhaust gas color	Quick acceleration (Low idling→High idling)	Bosch Scale	Max. 4.0	6.0
		At rated output		Max. 2.0	3.5
		At high idling		Max. 2.0	3.0
	Valve clearance (when engine is hot or cold.)	Intake valve	mm	0.4	-
		Exhaust valve	mm	1.0	-
Engine body	Compression Pressure (SAE30 oil)	Oil temperature: 40° C to 60° C (Engine speed)	Kg/cm² (rpm)	Min. 26 (210 - 250)	18 (210 - 250)
	Blow-by pressure (SAE30 oil)	At rated output Water temperature: Min. 70° C	mmH_2O	Max. 400	800
Lubrication system	Oil Pressure (Oil temperature: Min. 80° C)	At rated output SAE30 oil	Kg/cm²	3.5 - 5.0	2.5
		SAE10W oil	Kg/cm²	3.0 - 4.5	2.1
		At low idling SAE30 oil	Kg/cm²	Min. 1.5	0.7
		SAE10W oil	Kg/cm²	Min. 1.0	0.7
	Oil temperature	All speed (oil in oil pan)	° C	80 - 110	120
	Oil consumption ratio	At continuous rated output (Ratio of fuel consumption)	%	Max. 0.5	1.0
Fuel system	Fuel injection pressure	Nozzle tester	Kg/cm²	265^{+13}_{+5}	239
	Fuel injection timing	B.T.D.C	degree	38 ± 1	38 ± 1
Cooling system	Radiator pressure valve	Opening pressure (Differential pressure)	Kg/cm²	0.75 ± 0.1	0.75 ± 0.1
	Fan speed	At rated engine speed	rpm	950 ± 25	950 ± 25
	Fan belt tension	Deflects when pushed with a force of 6 kg	mm	See page 12 - 011	

★ The values given in the Testing and Adjusting data are NOT for adjustment of the output. Do not use these values as a guide to change the setting of the fuel injection pump.

Engine model				BSA6D170A-1			
Applicable machine model				BH60 / BH70		210M	
Classification	Paramete	Condition,etc	Unit	Standard	Tolerance	Standard	Tolerance
Performance	Engine speed	Highidling speed	rpm	2365 ± 35	-	2365 ± 35	-
		Low idling speed	rpm	925 ± 25	-	925 ± 25	-
	Necessary	0° C	rpm	Min. 80	-	Min. 80	-
	Starting speed	- 20° C (with starting aid)	rpm	Min. 80	-	Min. 80	-
Intake and exhaust system	Intake resistance	At all speed	mmH_2O	Max. 300	Max. 635	Max. 300	Max. 635
	Allowable Ex. back pressure	At rated output	mmHg	Max. 75	-	Max. 75	-
	Exhaust temperature (Turbine inlet temp.)	All speed	° C	Max. 680	Max. 700	Max. 680	Max. 700
	Exhaust gas color	At rated output	Bosch	Max. 3.0	Max. 5.0	Max. 3.0	Max. 5.0
		At high idling	Unit	Max.2.5	Max. 3.5	Max.2.5	Max. 3.5
	Valve clearance (when engine is hot or cold.)	Intake valve	mm	0.4	-	0.4	-
		Exhaust valve	mm	1.0	-	1.0	-
Engine body	Compression Pressure (SAE30 oil)	Oil temperature: 40° C to 60° C (Engine speed)	Kg/cm^2 (rpm)	Min. 26 (200 - 250)	18 (200 - 250)	Min. 26 (200 - 250)	18 (200 - 250)
	Blow-by pressure (SAE30 oil)	At rated output Water temperature: Min. 70° C	mmH_2O	Max. 400	Max. 700	Max. 400	Max. 700
Lubrication system	Oil Pressure (Oil temperature: Min. 80° C)	At rated output SAE30 oil	Kg/cm^2	3.0 - 5.0	Min. 2.0	3.0 - 5.0	Min. 2.0
		SAE10W oil	Kg/cm^2	2.5 - 4.5	Min. 2.0	2.5 - 4.5	Min. 2.0
		At low idling SAE30 oil	Kg/cm^2	Min. 1.5	Min. 0.7	Min. 1.5	Min. 0.7
		SAE10W oil	Kg/cm^2	Min. 1.0	Min. 0.7	Min. 1.0	Min. 0.7
	Oil temperature	All speed (oil in oil pan)	° C	80 - 110	Max. 120	80 - 110	Max. 120
	Oil consumption ratio	At continuous rated output (Ratio of fuel consumption)	%	Max. 0.5	Max. 1.0	Max. 0.5	Max. 1.0
Fuel system	Fuel injection pressure	Nozzle tester	Kg/cm^2	300 ± 10	Min. 240	300 ± 10	Min. 240
	Fuel injection timing	B.T.D.C Without timer	degree	39 ± 1	39 ± 1	39 ± 1	39 ± 1
		With timer		36 ± 1	36 ± 1	36 ± 1	36 ± 1
Cooling system	Radiator pressure valve	Opening pressure (Differential pressure)	Kg/cm^2	0.75 ± 0.1	0.65 - 0.85	0.75 ± 0.1	0.65 - 0.85
	Fan speed	At rated engine speed	rpm	1260 ± 40	1220 - 1300	1260 ± 40	1220 - 1300
	Fan belt tension	Deflects when pushed with a force of 6 kg	mm	13	10 - 16	13	10 - 16

★ The values given in the TESTING AND ADJUSTING DATA are NOT for adjustment of the output.
Do not use these values as a guide to change the setting of the fuel injection pump.

Engine model				BSA6D170AG-1	
Applicable machine model				BDG500 / BDG550	
Classification	Paramete	Condition,etc	Unit	Standard	Tolerance
Performance	Engine speed	Highidling speed	rpm	1545 ± 15	1545 ± 15
		Low idling speed	rpm	1000 ± 25	1000 ± 25
	Necessary	0° C	rpm	Min. 80	-
	Starting speed	- 20° C (with starting aid)	rpm	Min. 80	-
Intake and exhaust system	Intake resistance	At all speed	mmH_2O	Max. 450	635
	Intake pressure	At rated output	mmHg	-	-
	pressure				
	Exhaust temperature	All speed	° C	Max. 650	Max. 650
	(Turbine inlet temp.)				
	Exhaust gas color	At rated output	Bosch	Max. 9.8	-
		At high idling	Unit	Max. 2.0	2.5
	Valve clearance	Intake valve	mm	0.4	-
	(when engine is				
	hot or cold.)	Exhaust valve	mm	1.0	-
Engine body	Compression	Oil temperature:			
	Pressure	40° C to 60° C	Kg/cm^2	Min. 26	18
	(SAE30 oil)	(Engine speed)	(rpm)	(210 - 250)	(210 - 250)
	Blow-by pressure	At rated output			
	(SAE30 oil)	Water temperature: Min. 70° C	mmH_2O	Max. 280	400
Lubrication system		At rated output			
	Oil Pressure	SAE30 oil	Kg/cm^2	2.5 - 4.0	2.5 - 4.0
		SAE10W oil	Kg/cm^2		
	(Oil temperature:	At low idling			
	Min. 80° C)	SAE30 oil	Kg/cm^2	Min. 1.5	Min. 0.7
		SAE10W oil	Kg/cm^2	Min. 1.0	Min. 0.7
	Oil temperature	All speed (oil in oil pan)	° C	80 - 110	Max. 120
	Oil consumption	At continuous rated output	%	Max. 0.5	Max. 1.0
	ratio	(Ratio of fuel consumption)			
Fuel system	Fuel injection				
	pressure	Nozzle tester	Kg/cm^2	300 ± 10	Min. 240
	Fuel injection	B.T.D.C	degree	39 ± 1	39 ± 1
	timing				
Cooling system	Radiator pressure	Opening pressure	Kg/cm^2	0.75 ± 0.1	0.75 - 0.1
	valve	(Differential pressure)			
	Fan speed	At rated engine speed	rpm	1024 ± 25	-
	Fan belt tension	Deflects when pushed	mm	-	-
		with a force of 6 kg			

★ The values given in the TESTING AND ADJUSTING DATA are NOT for adjustment of the output.
Do not use these values as a guide to change the setting of the fuel injection pump.

TROUBLESHOOTING

CONTENTS

POINTS TO REMEMBER WHEN TROUBLESHOOTING

Troubleshooting means locating the basic cause of the failure, and carrying out swift repairs, and ensuring that the failure does not occur again.
When carrying out troubleshooting, it is of course important to understand the structure and function. But to carry out the troubleshooting effectively, a quick method is to carry out troubleshooting using the problems mentioned by the operator as a guide in locating the cause.

1. Do not disassemble the machine simply because there is a failure.

If the machine is disassembled immediately just because there is a failure:

- Unrelated or unnecessary places are also disas sembled
- It becomes difficult to locate the cause of the failure

This means that there is not only a waste of time and money on replacement parts, oil, and grease, but this action will also lose the confidence of the user and operator.

For this reason also, it is important to carry out troubleshooting based on full investigation before starting and troubleshooting following the correct order.

2. Questions to ask the user and operator

1) Are there any problems other than those already reported ?
2) Did anything unusual happen before the failure occurred ?
3) Did the failure occur suddenly, or had the condition of the machine been poor before the failure occurred ?
4) What were the conditions when the failure occurred?
5) Had any repairs been carried out before the failure occurred ?
6) Had any similar failure occurred before ?

3. Checks before troubleshooting

1) Check the oil level
2) Check for any external leakage of oil from the piping and hydraulic equipment.
3) Check the travel of the control levers.
4) Other maintenance items can also be carried out visually, so carry out any check that is considered necessary.

4. Confirming failure

Check the degree of the problem to judge for yourself if it is really a failure, or if there is some problem in the handling or operation of the machine.

★ When driving the machine and re-enacting the failure, be sure that the investigation or measurement does not make the failure worse.

5. Troubleshooting

Narrow down the causes of the failure from the results of the questions and checks in the above Items 2 - 4, then follow the troubleshooting flow chart to locate the failure.

★ Basic procedure for troubleshooting

1) Start from the simple places.
2) Start from the most probable places.
3) Investigate related parts also.

6. Basic action to remedy cause of failure

Even if the failure is repaired, if the root cause of the failure is not repaired, the same failure will occur again.
To prevent this, it is necessary to investigate why the failure occurred, and to remove the root cause of the failure.

METHOD OF USING TROUBLESHOOTING CHART

This troubleshooting chart is divided into three sections: **questions, check items, and troubleshooting.** The questions and check items are used to pinpoint high probability causes that can be located from the failure symptoms or simple inspection without using troubleshooting tools.

Next, troubleshooting tools or direct inspection without using to check the high probability causes to make final confirmation.

[Questions]

Section **A + B** in the chart on the right corresponds to the items where answers can be obtained from the user. The items in **B** are items that can be obtained from the user, depending on the user's level.

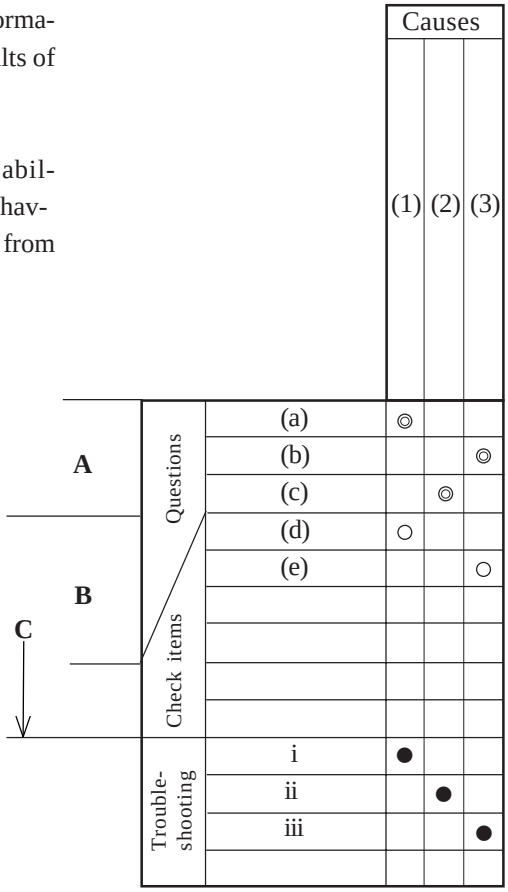
[**Check items**]

The serviceman carries out simple inspection to narrow down the causes. The items under **C** in the chart on the right correspond to this.

The serviceman narrows down the causes from information **A** that he has obtained from the user and the results of **C** that he has obtained from his own inspection.

[**Troubleshooting**]

Troubleshooting is carried out in the order of probability, starting with the causes that have been marked as having the highest probability from information gained from [**Questions**] and **[Check items].**



The basic method of using the troubleshooting chart is as follows.
Items listed for [**Questions**] and [**Check items**] that have a relationship with the cause items are marked with ○ , and of these, causes that have a high probability are marked with ◎.
Check each of the [**Questions**] and [**Check items**] in turn, and marked the ○ or ◎ in the chart for items where the problem appeared. The vertical column (Causes) that has the highest number of points is the most probable cause, so start troubleshooting for that item to make final confirmation of the cause.

❖1. For **[Confirm recent repair history]** in the **[Questions]** Section, ask the user, and mark thecause column with Δ to use as reference for locating thecause of the failure. However, do not use this when making calculations to narrow down thecauses.

❖2. Use the Δ in the cause column as reference for **[Degree of use(Operated for long period)]** in the **[Questions]** Section as reference. As a rule, do not use it when calculating the points for locating the cause, but it can be included if necessary to deter mine the order for troubleshooting.

			Causes						
			Seized turbocharger, interference	Clogged air cleaner element	Worn piston ring, cylinder	Clogged, seized injection nozzle	Improper injection timing	Defective injection pump (excessive injection)	
❖ 1	Confirm recent repair history								
❖ 2	Degree of use	Operated for long period	Δ	Δ	Δ				

Example of troubleshooting when exhaust gas is black

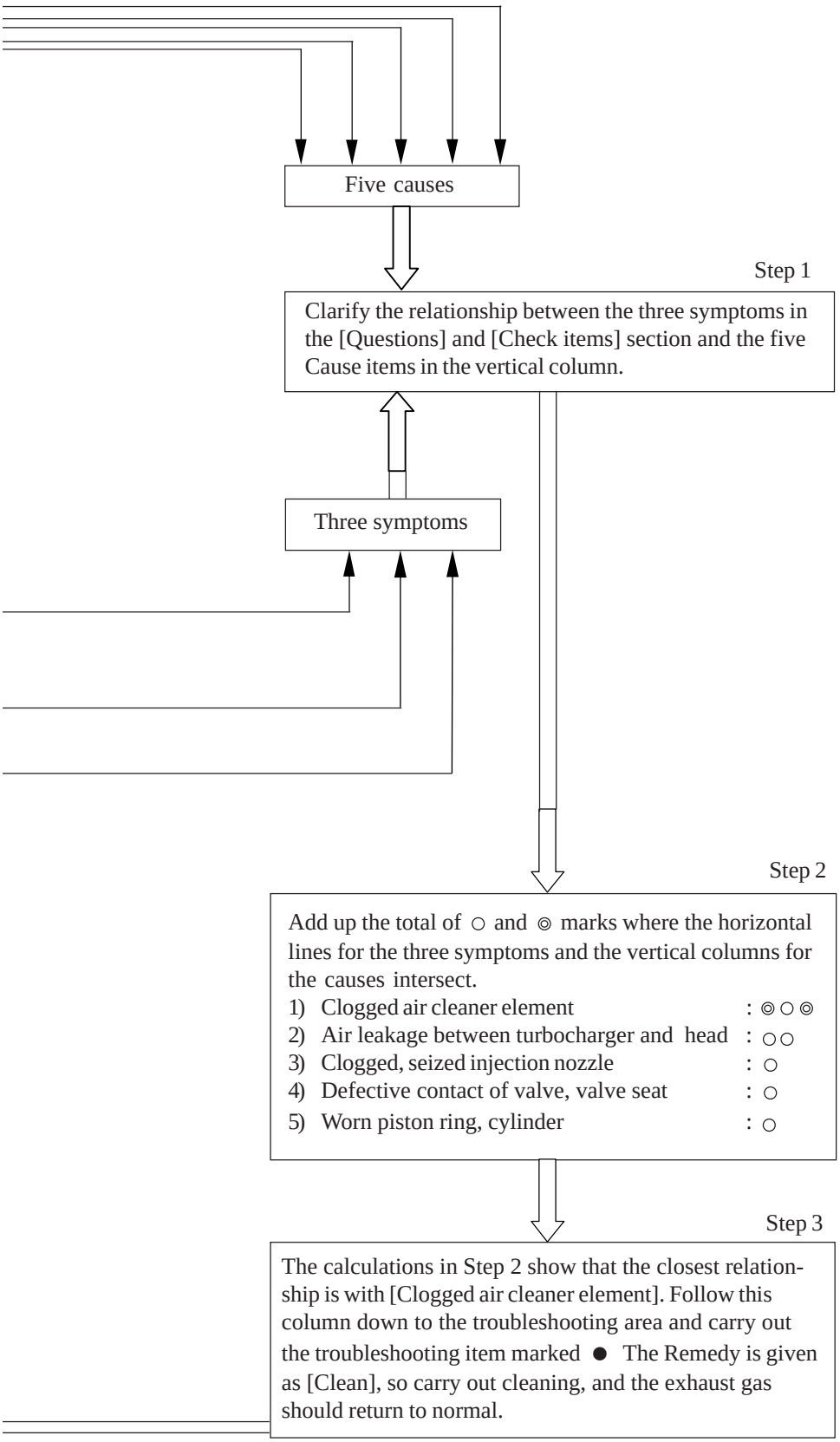
Let us assume [Clogged air cleaner] is taken to be the cause of black exhaust gas. Three symptoms have causal relationship with this problem: [Exhaust gas slowly become black.], [Power slowly become weaker], and [Dust indicator is red].
If we look from these three symptoms to find the causes, we find that there is a relationship with five causes. Let us explain here the method of using this causal relationship to pinpoint the most probable cause.

S-7 Exaust gas is black (incomplete combustion)

General causes why exhaust gas is black

- Insufficient intake air
- Improper condition of fuel injection
- Excessive injection of fuel

			Causes											
			Seized turbocharger, interference	Clogged air cleaner element	Worn piston ring, cylinder	Clogged, seized injection nozzle	Imprper injection timing	Defective injection pump (excessive injection)	Improper valve clearance	Crushed, clogged muffler	Leakage of air between turbocharger and head	Defective contact of valve, valve seat	Defective injection pump (rack, plunger seized)
Questions	Confirm recent repair history												
	Degree of use	Operated for long period			Δ	Δ						Δ	
	Color of exhaust gas	Suddenly become black	◎			○							○
		Gradually become black											
		Blue under light load			◎								
	Engine oil must be added more frequently				◎								
	Power was lost	Suddenly	◎			○				○			○
		Gradually											
	Non-specified fuel has been used					○							○
Check items	Noise of interference is heard from around turbocharger		◎										
	Dust indicator is red												
	Blow-by gas is excessive				◎								
	Engine pickup is poor and combustion is irregular		○			◎			○	○	○		○
	When exhaust manifold is touched immediatly after starting engine. temperature of some cylinder is low					◎							○
	Match marks on fuel injection pump are out of alignment						◎						
	Seal on injection pump has come off							◎					
	Clanging sound is heard from around cylinder head								◎				
	Exhaust noise is abnormal		○			○				◎			
	Muffler is crushed									◎			
	Leakage of air between turbocharger and head loose clamp										◎		
Troubleshooting	When turbocharger is rotated by hand, it is found by heavy		●										
	When air cleaner is inspected directly, it is found to be clogged												
	When compression pressure is measured, it is found to be low				●							●	
	Speed of some cylinders does not change when operating on reduced cylinders					●							
	When check is made using delivery method, injection timing is found to be incorrect						●						
	Injection pump test shows that injection amount is incorrect							●					
	When valve clearance is checked directly it is found to be outside standard value								●				
	When muffler is removed, exhaust gas color returns to normal									●			
	When control rack is pushed, it is found to be heavy or does not return												●
		Remedy	Replace	Clean	Replace	Replace	Adjust	Adjust	Adjust	Replace	Repair	Replace	Replace


Five causes
Step 1
Clarify the relationship between the three symptoms in the [Questions] and [Check items] section and the five Cause items in the vertical column.
Three symptoms
Step 2
Add up the total of ○ and ◎ marks where the horizontal lines for the three symptoms and the vertical columns for the causes intersect.
1) Clogged air cleaner element : ◎○◎
2) Air leakage between turbocharger and head : ○○
3) Clogged, seized injection nozzle : ○
4) Defective contact of valve, valve seat : ○
5) Worn piston ring, cylinder : ○
Step 3
The calculations in Step 2 show that the closest relationship is with [Clogged air cleaner element]. Follow this column down to the troubleshooting area and carry out the troubleshooting item marked ● The Remedy is given as [Clean], so carry out cleaning, and the exhaust gas should return to normal.

S-1 Starting performance is poor (Starting always takestime)

General causes why exhaust gas comes out but engine does not start

- Defective electrical system
- Insufficient supply of fuel
- Insufficient intake of air
- Improper selection of fuel (At ambient temperature of -10° C or below, use ASTM D975 No. 1)
  - ★ Battery charging rate

Ambient temperature \ Charging rate	100 %	90 %	80 %	75 %	70 %
20° C	1.28	1.26	1.24	1.23	1.22
0° C	1.29	1.27	1.25	1.24	1.23
-10° C	1.30	1.28	1.26	1.25	1.24

- The specific gravity should be for the charging rate of 70% or more in the above table.
- In cold weather the specific gravity must be for the charging rate of at least 75% in the above table.

			Causes: Worn piston ring, cylinder	Defective contact of valve, valve seat	Clogged air cleaner element	Clogged fuel filter, strainer	Clogged feed pump strainer	Defective APS device	Defective regulator	Defective alternator	Defective or deteriorated battery	Defective injection nozzle	Defective injection timing	Defective injection pump (rack, plunger stuck)	Leakage, clogging, air in fuel system	Clogged fuel tank air breather hole	Defective injection pump overflow valve	Engine oil viscosity is too high
Questions	Confirm recent repair history																	
	Degree of use	Operated for long period			Δ	Δ	Δ				Δ							
	Ease of staritng	Gradually become black	◎	◎	○	○	○											
		Start when warm						◎			◎							◎
	Indicator lamp does not light up							◎										
	Engine oil must be added more frequently		◎															
	Replacement of filters has not been carried out according to operation manual			◎	◎	◎					○		○					
	Dust indicator is red			◎														
	Non-specified fuel has been used				○	○					○		○					
	Type of oil is not used according to operation manual																	◎
Check items	Battery charge lamp is ON								◎	◎								
	Starting motor cranks engine slowly										◎							◎
	When exhaust manifold is touched immediatly after starting engine. temperature of some cylinder is low											◎						
	Engine does not pick up smoothly, and combustion is irregular			○								◎						
	Blow-by gas is excessive																	
	Match marks on fuel injection pump are out of alignment												◎					
	Mud is stuck to fuel tank cap															○		
	When engine is cranked with starting motor, 1) Little fuel comes out even when injection pump sleeve nut is loosened													◎				
	2) Little fuel comes out even when fuel filter air bleed plug is loosened				◎	◎								◎				
	Leakage from fuel piping													○	◎			
	Ther is hunting from engine (rotation is irregular)				○	○									◎	○	◎	
Troubleshooting	When compression pressure is measured, it is found to be low		●	●														
	When air cleaner element is inspected directly, it is found to be clogged				●													
	When fuel filter, strainer are inspected directly, they are found to be clogged					●									●			
	When feed pump strainer is inspected directly, it is found to be clogged						●											
	APS combustion portion does not become warm							●										
	Voltage is 26 - 30V between alternator terminal B and terminal E with engine at low idling	Yes							●									
		No								●								
	Either specific gravity of electrolyte or voltage of battery is low										●							
	Some cylinder does not change engine speed when operating on reduced cylinder											●						
	When check is made using delivery method, injection timing is found to be incorrect												●					
	When control rack is pushed, it is found to be heavy or does not return (when blind plug at rear of pump is removed, it can be seen that plunger control sleeve does not move)													●				
	When fuel cap is inspected directly, it is found to be clogged															●		
	When overflow valve is inspected, it is found to be stiff, or always stays open																●	
	Remedy		Replace	Repair	Clean	Clean	Clean	Replace	Replace	Replace	Replace	Replace	Adjust	Replace	Repair	Clean	Replace	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-2 Engine does not start

① Engine does not turn

General causes why does not turn

- Internal parts of engine seized
  - ★ If internal parts of the engine are seized, carry out trouble-shooting for “Engine stops during operations”
- Failure in power train
- Defective electrical system

			Causes										
			Defective wiring of starting circuit	Defective or deteriorated battery	Defective starting motor	Broken ring gear	Defective saftey relay or safety switch	Defective battery relay	Defective battery terminal connection	Defective adjustment of engine stop motor wire	Defective engine stop motor	Defective starting switch
Questions / Check items	Confirm recent repair history											
	Degree of use	Operated for long period		Δ		Δ						
	Condition of horn when starting switch is turned ON	Horn does not sound	◎						○			○
		Horn sound level is low		◎								
	When starting switch is turned to START, pinion moves out,but	Rotating speed is slow		◎								
		Makes grating noise			◎	◎						
		Soon disengages again					◎					
		Makes rattling noise and does not turn		○	○		○					
	When starting switch is turned to START, pinion does not move out		◎	○								○
	When starting switch is turned to ON, there is no clicking spund		Carry out troubleshooting for defective wiring of starting circuit	○				◎				
	Battery terminal is loose								◎			
	When starting switch is turned to ON, linkage does not move									◎	◎	
	When battery is checked, battery electrolyte is found to be low			◎								
Troubleshooting	Specification gravity of electrolyte, voltage of battery is low			●								
	For the following conditions 1) - 5), turn the starting switch OFF, connect the cord, and carry out troubleshooting at ON											
	1) When terminal B and terminal C of starting switch are connected, engine starts											●
	2) When terminal B and terminal C of starting motor are connected, engine starts				●							
	3) When terminal B and terminal C of safety relay are connected, engine starts						●					
	4) When terminal of safety switch and terminal B of starting motor are connected, engine starts						●					
	5) There is no 24V voltage between terminal B and terminal E of battery relay							●				
	When ring gear is inspected directly, tooth surface is found to be chipped					●						
	Does not move even when engine stop motor linkage is disconnected									●	●	
		Remedy	-	Replace	Replace	Replace	Replace	Replace	Replace	Adjust	Replace	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

② Engine turns but no exhaust gas comes out (Fuel is not being injected)

General causes why engine turns but no exhaust gas comes out

- Supply of fuel impossible
- Supply of fuel is extremely small
- Improper selection of fuel (particularly in winter)

Standards for use of fuel

KIND OF FLUID	AMBIENT TEMPERATURE				
	14	32	50	68	86 °F
	10	0	10	20	30° C
Diesel fuel	ASTM D975 No.2				
	ASTM D975 No. 1				

		Causes										
		Bloken, injection pump drive shaft, key	Defective injection pump (rack, plunger seized)	Seized, broken feed pump piston	Clogged fuel filter, strainer	Clogged feed pump strainer	Lack of fuel	Clogged, leaking fuel piping	Clogged fuel tank air breather hole	Defective engine stop motor	Iproper fuel used
Questions	Confirm recent repair history										
	Degree of use — Operated for long period				Δ	Δ			Δ		
	Exhaust gas suddenly (when starting again) stopped coming out	◎	◎	◎					○		
	Replacement of filters has not been carried out according to operation manual				◎	◎					
	Fuel tank is found to be empty						◎				
	There is leakage from fuel piping, crushed piping							◎			
	Mud is stuck to fuel tank cap								◎		
Check items	When starting switch is turned ON, linkage does not move									◎	
	When fuel filter is drained, fuel does not come out										◎
	When engine is cranked with starting motor, 1) No fuel comes out even when fuel filter air bleed plut is loosened	◎			○	○					○
	2) No fuel spurts out even when injection pipe sleeve nut is loosened	◎	◎	◎							
	Rust and water are found when fuel is drained				○	○					
Troubleshooting	Inspect injection pump directly	●									
	When control rack is pushed, it is found to be heavy or does not return		●								
	Inspect feed pump directly			●							
	When fuel filter, strainer are inspected directly, they are found to be clogged				●						●
	When feed pump strainer is inspected directly, it is found to be clogged					●					
	When fuel cap is inspected directly, it is found to be clogged								●		
	Does not move even when engine stop motor linkage is disconnected									●	
	Remedy	Replace	Replace	Replace	Clean	Clean	Add	Repair	Repair	Replace	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

③ Exhaust gas comes out but engine does not start (Fuel is being injected)

General causes why exhaust gas comes out but engine does not start

- Lack of rotating force due to defective electrical system
- Insufficient supply of fuel
- Insufficient intake of air
- Improper selection of fuel and oil

			Causes													
			Defective, broken valve system (vlave,rocker lever,etc.)	Defective injection pump (rack, plunger stuck)	Worn piston ring, cylinder liner	Clogged fuel filter, strainer	Clogged feed pump strainer	Clogged air cleaner element	Defective APS device	Defective or deteriorated battery	Leakage, clogging, air in fuel system	Clogged injection nozzle, defective spray	Clogged fuel tank air breather hole	Improper fuel, oil used	Defetive fuel control lever linkage
Questions	Confirm recent repair history														
	Degree of use	Operated for long period			Δ	Δ	Δ					Δ			
	Suddenly failed to start		◎	◎											
	When engine is cranked, abnormal noise is heard from around cylinder head		◎												
	Engine oil must be added more frequently				◎										
	Non-specified fuel had been used			○								○			
	Replacement of filter has not been carried out according to operation manual					◎	◎	◎							
	Type of oil is not used according to operation manual													◎	
	Rust is found when fuel is drained					◎	◎								
	Dust indicator is red							◎							
	Indicator lamp does not light up								◎						
Check items	Starting motor cranks engine slowly									◎				◎	
	Mud is stuck to fuel tank cap												○		
	When fuel lever is placed at FULL position, it does not contact stopper			○											○
	When engine is cranked with starting motor, 1) Little fuel comes out even when injection pump sleeve nut is loosened			◎											○
	2) Little fuel comes out even when fuel filter air bleed plug is loosened					◎	◎							○	
	There is leakage, from fuel piping										◎				
	When exhaust manifold is touched immediately after starting engine, temperature of some cylinder is low											◎			
	When fuel filter is drained, no fuel comes out													◎	
	Even when fuel control lever is moved, fuel injection pump lever does not move														◎
Troubleshooting	Remove head cover and inspect directly		●												
	When control rack is pushed, it is found to be heavy or does not return			●											
	When compression pressure is measured, it is found to be low				●										
	When fuel filter, strainer are inspected directly, they are found to be clogged					●								●	
	When feed pump strainer is inspected directly, it is found to be clogged						●								
	When air cleaner element is inspected directly, it is found to be clogged							●							
	APS combustion portion does not become warm even when starting switch is turned to HEAT								●						
	Either specific gravity of electrolyte or voltage of battery is low									●					
	When feed pump is opaerated, there is no response or pump is heavy										●				
	Speed of some cylinder does not change when operating on reduced cylinder											●			
	When fuel cap is inspected directly, it is found to be clogged												●		
	Pay, stiffness in fuel control lever linkage														●
	Remedy		Replace	Replace	Replace	Clean	Clean	Clean	Repair	Replace	Repair	Clean	Clean	Replace	Repair

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-3 Exhaust does not pick up smoothly (Follow-up is poor)

General causes why engine does not pick up smoothly

- Insufficient intake of air
- Insufficient supply of fuel
- Improper condition of fuel injection
- Use of improper fuel
- Defective fuel injection pump

			Causes													
			Clogged air cleaner element	Clogged fuel filter, strainer	Clogged feed pump strainer	Clogged injection nozzle, defective spray	Defective feed pump	Worn piston ring, cylinder	Seized turbocharger, interference	Improper valve clearance	Clogged fuel tank air breather hole	Clogged, leaking fuel piping	Defective contact of valve, valve seat	Improper adjustment of injection pump stop lever	Broken injection pump boost compensator diaphragm broken air pump
Questions	Confirm recent repair history														
	Degree of use	Operated for long period			Δ	Δ	Δ					Δ			
	Replacement of filter has not been carried out according to operation manual		◎	◎											
	Non-specified fuel has been used		◎												
	Engine oil must be added more frequently				◎										
	Dust indicator is red			○								○			
	Noise of interference is heard from around turbocharger					◎	◎	◎							
Check items	Engine pick-up suddenly poor													◎	
	Color of exhaust gas	Blue under light load				◎	◎								
		Black						◎							
	Clanging sound is heard from around cylinder head								◎						
	Mud is stuck to fuel tank cap									◎				◎	
	There is leakage, from fuel piping												○		
	High idling speed under no load is normal, but speed suddenly drops when load is applied			○											○
	There is hunting from engine (rotation is irregular)			◎											○
	When exhaust manifold is touched immediatly after starting engine, temperature of some cylinder is low					◎	◎				◎			○	
	Blow-by gas is excessive											◎			
Troubleshooting	When air cleaner element is inspected directly, it is found to be clogged														
	When fuel filter, strainer are inspected directly, they are found to be clogged													◎	
	When feed pump strainer is inspected directly, it is found to be clogged														◎
	Some cylinders does not change engine speed when operating on reduced cylinder		●												
	Inspect feed pump			●											
	When compression pressure is measured, it is found to be low				●										
	When turbocharger is rotated by hand, it is found to be heavy					●								●	
	When valve clearance is checked directly, it is found to be outside standard value						●								
	When fuel cap is inspected directly, it is found to be clogged							●							
	When feed pump is opaerated, operation is too light or too heavy When starting switch is turned ON, there is a clearance between stop lver and stopper								●						
	bolt									●					
	When boost compensator diaphram is inspected it is found to be broken, or pipe is										●				
	crushed											●			
	Remedy		Clean	Clean	Clean	Repair	Replace	Replace	Replace	Adjust	Clean	Repair	Replace	Adjust	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-4 Enigne stops during operations

General causes why engine stops during operations

- Internal parts of engine seized
- Insufficient supply of fuel
- Overheating
  - ★ If there is overheating and the engine stops, carry out troubleshooting for overheating.
- Failure in power train
  - ★ If the engine stops because of a failure in the power train, carry out troubleshooting for the chassis.

			Causes															
			Broken, seized piston, connecting rod	Broken, seized crankshaft bearing	Broken valve system (valve, rocker lever, etc.)	Broken, seized gear train	Broken pump auxiliary equipment	Broken fuel pump drive shaft, key	Lack of fuel	Clogged fuel filter, strainer	Clogged feed pump strainer	Broken, seized feed pump piston	Clogged leaking fuel piping	Clogged fuel tank air breather hole	Defective injection pump (rack, plunger stuck)	Failure in chassis power train
Questions	Confirm recent repair history															
	Degree of use	Operated for long period								Δ	Δ					
	Condition when engine stooped	Abnormal noise was heard and engine stopped suddenly	◎	◎	◎	◎	◎	◎				○			○	◎
		Engine overheated and stopped	◎	○			○									
		Engine stopped slowly							◎	○	○					
		There was hunting and engine stopped							◎	○	○			○		
	Fuel gauge lamp lights up								◎							
	Fuel tank is found to be empty								◎							
	Replacement of filters has not been carried out according to operation manual									◎	◎					
	Non specified fuel has been used									○	○	○			○	
Check items	When feed pump is operated, there is no response or it is heavy									○	○		◎			
	Mud is stuck to fuel tank cap													◎		
	Engine turns, but stops when transmission control lever is operated															◎
	Try to turn by hand using barring tool	Does not turn at all	◎	◎												
		Turns in opposite direction			◎											
		Moves amount of backlash				◎	◎									
		Shaft does not turn						◎								
	Rust and water are found when fuel is drained									◎	◎					
	Metal particales are found when oil is drained		◎	◎						○	○					
Troubleshooting	Remove oil pan and inspect directly		●	●												
	Remove head cover and inspect directly				●											
	When gear train is inspected, it does not turn					●										
	Turns when pump auxiliary equipment is removed						●									
	When fuel filter, strainer are inspected directly, they are found to be clogged									●						
	When feed pump strainer is inspected directly, it is found to be clogged										●					
	Inspect feed pump											●				
	When control rack is pushed, it is found to be heavy or does not return														●	
	Remedy		Replace	Replace	Replace	Replace	Replace	Replace	Add	Clean	Clean	Replace	Repair	Clean	Replace	I

Carry out troubleshooting in chassis volume

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-5 Enigne does not rotate smoothly (hunting)

General causes why engine does not rotate smoothly

- Air in fuel system
- Defective governor mechanism

			Causes: Defective operation of governor	Defective adjustment of governor	Defective operation of control rack	Low speed is too low	Lack of fuel	Clogged feed pump strainer	Clogged fuel filter, strainer	Clogged, air in circuit between fuel tank and feed pump	Clogged, air in circuit between feed pump and zozzle	Clogged fuel tank air breather hole	Defective fuel feed pump
Questions	Confirm recent repair history												
	Degree of use	Operated for long period						Δ	Δ				
	Condition of hunting	Occurs at fixed speed range	◎	◎	◎	○							
		Occurs at low idling	○			◎		○	○	○	○		
		Occurs even when speed is raised	○	○	○							○	
		Ocuurs on slops					◎						
	Fuel tank is found to be empty						◎						
	Replacement of filters has not been carried out according to operation manual							◎	◎				
	Rust is found when fuel is drained							○	○				
Check items	Leakage from fuel piping									◎	◎		
	When feed pump is operated, 1) No response, light, return is quick									◎	◎		
	2) No response, light, return is normal									◎			
	Engine speed sometimes changes grealty		◎	◎									◎
	Sometimes difficult to stop engine		◎		◎								
	Seal on injection pump has come off			◎		◎							
Troubleshooting	When governor lever is moved it is found to be stiff		●		●								
	When injection pump is tested, governor is found to be improperly adjusted			●									
	When control rack is pushed, it is found to be heavy or does not return				●								
	When fuel cap is inspected directly, it is found to be clogged					●						●	
	When feed pump strainer is inspected directly, it is found to be clogged							●					
	When fuel filter, strainer are inspected directly, they are found to be clogged								●				
	Check fuel feed pump												●
		Remedy	Adjust	Adjust	Adjust	Adjust	Add	Clean	Clean	Repair	Repair	Clean	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-6 Engine lacks output (no power)

Carry out troubleshooting to decide if the cause is in the engine or in the machine. (Measure engine stall speed)

General causes why engine lacks output

- Insufficient intake of air
- Insufficient supply of fuel
- Improper condition of fuel injection
- Use of improper fuel
  (If non-specified fuel is used, output drops)
- Lack of output due to overheating
  - ★ If there is overheating and lack of output, carry out troublshooting for overheating.

			Causes																
			Clogged air cleaner element	Seized turbocharger, interference	Worn piston ring, cylinder	Clogged fuel filter, strainer	Clogged feed pump strainer	Clogged injection nozzle, defective spray	Seized injection pump plunger	Improper valve clearance	Defective contact of valve, valve seat	Bent fuel lever linkage, Defective adjustment	Clogged, leaking fuel piping	Clogged fuel tank air breather hole	Broken injection pump boost compensator diaphragm	Incorrect position of stop lever	Oil level too high
Questions	Confirm recent repair history																
	Degree of use	Operated for long period	Δ		Δ	Δ	Δ				Δ						
	Power was use	Suddenly		◎													
		Gradually	○		○	○	○	○			○						
	Engine oil must be added more frequently				◎												○
	Replacement of filter has not been carried out according to operation manual		◎			◎	◎										
	Non-specified fuel has been used					◎	◎	◎	◎								
	Dust indicator is red		◎														
Check items	Color of exhaust gas	Black	◎	◎													
		Blue under light load			◎												
	Noise of interference is heard from around turbocharger			◎													
	Blow-by gas is excessive				◎												
	Engine pick-up is poor and combustion is irregular			◎				○					○	○	○	○	
	High idling speed under no load is normal, but speed suddenly drops when load is applied					◎	◎							○			
	When exhaust manifold is touched immediatly after starting engine, temperature of some cylinder is low							◎	○								
	There is hunting from engine (rotation is irregular)					○	○						○	○			
	Clanging sound is heard from around cylinder head									◎							
	High idling speed of engine is low								○			◎					
	Leakage from fuel piping												◎				
	When injection pipe is held between fingers, there is no pulse, or there are cylinder with a weak pulse								◎								
Troubleshooting	When air cleaner element is inspected directly, it is found to be clogged		●														
	When turbocharger is rotated by hand, it is found to be heavy			●													
	When compression pressure is measured, it is found to be low				●						●						
	When fuel filter, strainer are inspected directly, they are found to be Clogged					●											
	When feed pump strainer is inspected directly, it is found to be clogged						●										
	Some cylinders does not change engine speed when operating on reduced cylinder							●	●								
	When control rack is pushed, it is found to be heavy or does not return								●								
	When valve clearance is checked directly, it is found to be outside standard value									●							
	When lever is placed at FULL position, it does not contact stopper											●					
	When feed pump is opaerated, operation is too light or too heavy												●				
	When fuel cap is inspected directly, it is found to be clogged													●			
	Remedy		Clean	Replace	Replace	Clean	Clean	Repair	Replace	Adjust	Replace	Adjust	Repair	Clean	Go to S-3 Engine does not pick up smoothly				

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-7 Exhaust gas is black (incomplete combustion)

General causes why exhaust gas is black

- Insufficient intake of air
- Improper condition of fuel injection
- Excessive injection of fuel

			Causes												
			Seized turbocharger, interference	Clogged air cleaner element	Worn piston ring, cylinder	Clogged, seized injection nozzle	Improper injection timing	Defective injection pump (excessive injection)	Improper valve clearance	Crushed, clogged muffler	Leakage of air between turbocharger and cylinder head	Defective contact of valve, valve seat	Defective injection pump (rack, plunger seized)	Defective APS nozzle
Questions	Confirm recent repair history													
	Degree of use	Operated for long period		Δ	Δ	Δ						Δ		
	Color of exhaust gas	Suddenly became black	◎			○							○	
		Gradually became black		◎		○					○			
		Blue under light load			◎									
	Engine oil must be added more frequently				◎									
	Power was lost	Suddenly	◎			○				○			○	
		Gradually		○	○						○	○		
	Non-specified fuel has been used					○							○	
Check items	Noise of interference is heard from around turbocharger		◎											
	Dust indicator is red			◎										
	Blow-by gas is excessive				◎									
	Engine pick-up is poor and combustion is irregular		○			◎			○	○	○		○	
	When exhaust manifold is touched immediatly after starting engine, temperature of some cylinder is low					◎							○	
	Match marks on fuel injection pump are out of alignment						◎							
	Seal on injection pump has come off							◎						
	Clanging sound is heard from around cylinder head								◎					
	Exhaust noise is abnormal		○			○				◎				◎
	Muffler is crushed									◎				
	Leakage of air between turbocharger and head, loose clamp										◎			
Troubleshooting	When turbocharger is rotated by hand, it is found to be heavy		●											
	When air cleaner is inspected directly, it is found to be clogged			●										
	When compression pressure is measured, it is found to be low				●							●		
	Some cylinders does not change engine speed when operating on reduced cylinder					●								
	When check is made using delivery method, injection timing is found to be incorrect						●							
	Injection pump test shows that injection amount is incorrect							●						
	When valve clearance is checked directly, it is found to be outside standard value								●					
	When muffler is removed, exhaust gas color returns to normal									●				
	When control rack is pushed, it is found to be heavy or does not return												●	
	Remedy		Replace	Clean	Replace	Replace	Adjust	Adjust	Adjust	Replace	Repair	Replace	Replace	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-8 Oil consumption is excessive (or exhaust gas blue)

★ To prevent oil from leaking up or down, do not run the engine at idling for more than 20 minutes continuously.
(Both low and high idling)

General causes why oil consumption is excessive

- Abnormal combustion of oil
- External leakage of oil
- Wear of lubrication system

			Causes																
			Broken piston ring	Worn piston ring, cylinder liner	Clogged, breather or breather hose	Leakage from oil filter, oil cooler	Leakage from oil piping	Leakage from oil drain plug	Leakage from oil pan, cylinder head, etc.	Broken oil cooler	Turbocharger: Worn seal at turbine end	Turbocharger: Worn seal at blower end	Worn, broken rear seal, seal surface	Dust sucked in from intake system	Worn valve (stem, guide), broken seal	Broken injection pump boost compensator diaphragm	Oil level too high
Questions	Confirm recent repair history																
	Degree of use	Operated for long period		Δ							Δ	Δ			Δ		
	Oil consumption suddenly increased		◎							○						◎	◎
	Engine oil must be added more frequently			◎						○							
	Engine oil becomes contaminated quickly		○	◎	○												
Check items	Exhaust gas is blue under light load		◎	◎													
	Amount of blow-by gas	Abnormally excessive	◎	◎								○			○		
		None			◎												
	Area around engine is dirty with oil					◎	◎	◎	◎								
	There is oil in engine cooling water									◎							
	When exhaust pipe is removed, inside is found to be dirty with oil										◎				○	◎	
	Inside of turbocharger intake pipe is dirty with oil											◎					
	Oil level in clutch or TORQFLOW transmission damper case rises												◎				
	When oil level is checked with dipstick, it is found to be above H mark																◎
	Clamps for intake system are loose													◎			
	If engine is run at low idling, oil leaks from joint of turbocharger and exhasut mainfold																
Troubleshooting	Inside of joint bolt of injection pump and boost compensator pipe is wet with oil															●	
	When compression pressure is measured, it is found to be low		●	●													
	When breather element is inspected, it is found to be clogged with dirty oil				●												
	There is external leakage of oil from engine					●	●	●	●								
	Pressure-tightness test of oil cooler shows there is leakage									●							
	Excessive play of turbocharger shaft										●	●					
	Check rear seal directly												●				
	When intake manifold is removed, dust is found inside													●			
	When intake manifold is removed, inside is found to be dirty with oil														●		
	Remedy		Replace	Replace	Clean	Repair	Repair	Repair	Repair	Replace	Replace	Replace	Repair	Repair	Repair	Replace	Adjust

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-9 Oil becomes contaminated quickly

General causes why oil becomes contaminated quickly

- Intake of exhaust gas due to internal wear
- Clogging of lubrication passage
- Improper combustion
- Use of improper oil
- Operation under excessive load
- Interval between oil change is too long

			Causes										
			Worn piston ring, cylinder	Clogged, breather, breather tube	Clogged oil filter	Worn valve, valve guide	Clogged oil cooler	Clogged turbocharger drain pipe	Defective seal at turbocharger turbine end	Defective safety vavle	Exhaust gas is black	Oil level too high
Questions	Confirm recent repair history											
	Degree of use	Operated for long period	Δ			Δ			Δ			
	Engine oil must be added more frequently		◎									○
	Non-specified fuel has been used				○							
Check items	Color of exhaust gas	Blue under light load	◎									
		Black									◎	
	Amount of blow-by gas	Abnormally excessive	◎			○		○	○			
		None		◎								
	Oil filter caution lamp stays on even when oil pressure rises				◎					○		
	When oil filter is inspected, metal particles are found		○		◎	○						
	When exhaust pipe is removed, inside is found to be dirty with oil					◎						
	Engine oil temperature rises quickly						◎					◎
	When oil level is checked with dipstick, it is found to be above H mark											◎
Troubleshooting	When compression pressure is measured, it is found to be low		●			●					Carry out troubleshooting also for "Exhaust gas is black"	
	When breather element is inspected directly, it is found to be clogged with dirty oil, or hose is broken			●								
	When oil filter is inspected directly, it is found to be clogged				●							
	When oil cooler is inspected directly, it is found to be clogged						●					
	Turbocharger drain of turbocharger shaft							●				
	Excessive play of turbocharger shaft								●			
	When safety vavle is inspected directly, spring is found to be catching or broken									●		
Remedy			Replace	Clean	Replace	Replace	Clean	Clean	Replace	Replace	I	Adjust

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-10 Fuel consumption is excessive

General causes why fuel consumption is excessive

- Leakage of fuel
- Impoper condition of fuel injection
- Excessive injection of fuel

			Causes: Defective injection pump (excessive injection)	Defective injection nozzle spray	Defective injection pump plunger	Improper fuel injection timing	External leakage from fuel piping, fuel filter	Defective oil seal inside feed pump (piston)	Defective adjustment of fuel lever linkage	Defective injection nozzle (loose retaining cap)
Questions	Confirm recent repair history									
	Degree of use	Operated for long period		Δ	Δ			Δ		
	Condition of fuel consumption	More than for other machines of same model	◎			○				
		Gradually increased		○	○					
		Suddenly increased					○			
	Exhaust gas color	Black	◎	○		○			○	
		White								
Check items	Seal on injection pump has come off		◎							
	There is irregular combustion			◎						
	When exhaust manifold is touched immediately after starting engine, temperature of some cylinder is low			◎	○					
	Match mark on injection pump is missaligned					◎				
	There is external leakage of fuel from engine						◎			
	Engine oil level rises and smells of diesel fuel		○					◎		◎
	Engine low idling speed in high		○							
Troubleshooting	Injection pump test shows that injection amount is too high		●							
	Some cylinder does not change engine speed when operating on reduced cylinder			●						
	When control rack is pushed, it is found to be heavy or does not return				●					
	When check is made using delivery method, injection timing is found to be incorrect					●				
	Remove nozzle holder and inspect directly									●
	Remove feed pump and inspect directly							●		
	When engine speed is measured, low idling speed is found to be high								●	
		Remedy	Adjust	Replace	Replace	Adjust	Repair	Repair	Adjust	Repair

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-11 Oil is in cooling water, or water spurts back, or water level goes down

General causes why oil is in cooling water

- Internal leakage in lubrication system
- Internal leakage in cooling system

			Causes						
			Broken oil cooler core, O-ring	Broken cylinder head, cylinder head gasket	Insufficient protrusion of cylinder liner	Broken oil cooler for power train	Brocken cylinder liner O-ring holes caused by pitting	Internal cracks in cylinder block	Broken seal on water pump (breather hole clogged)
Questions	Confirm recent repair history								
	Degree of use	Operated for long period	Δ				Δ		
	Increase in oil level	Suddenly increased	○	○		○			
		Gradually increased					○	○	
Check items	Hard water is being used as cooling water (corrosion resistor valve is closed)		○				○		
	Engine oil level risen, oil is cloudy, white		◎				○	○	○
	Excessive air bubbles inside radiator, water spurts back			◎	◎				
	Hydraulic oil, torque converter, transmission oil is cloudy white					◎			
	When hydraulic oil, torque converter, transmission oil is drained, water comes out					◎			
Trouble shooting	Pressure-tightness test of oil cooler shows there is leakage		●			●			
	Pressure-tightness test of cylinder head shows there is leakage			●					
	Remove cylinder head and inspect directly				●				
	Remove oil pan and inspect directly						●	●	
	Inspect water pump								●
Remedy			Replace	Replace	Replace	Replace	Replace	Replace	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-12 Oil pressure lamp lights up (drop in oil pressure)

General causes why oil pressure lamp lights up

- Leakage, clogged ,wear of lubricating system
- Defective oil pressure control
- Use of improper oil (improper viscosity)
- Deterioration of oil due to overheating

★ Standards for engine oil selection

KIND OF FLUID	AMBIENT TEMPERATURE				
	14	32	50	68	86 °F
	-10	0	10	20	30° C
Enigne oil	SEA 10W	SAE 30			

			Causes															
			Clogged oil filter	Worn bearing journal	Clogged strainer inside oil pan	Clogged, broken oil pipe inside oil pan	Broken suction pipe brazing portion	Defective oil pump	Insufficient oil level in oil pan	Defective regulator valve	Defective relief valve	Leakage, crushed hydraulic piping	Defective oil level sensor	Defective oil pressure sensor	Water, fuel in oil	Clogged oil cooler
Questions	Confirm recent repair history															
	Degree of use	Operated for long period	Δ	Δ				Δ								
	Replacement of filters has not been carried out according to operation manual		◎													
	Caution lamp lights up		◎								◎					
	Non-specified fuel has been used		○	○												
Check items	Condition when oil pressure lamp lights up	Lights up at low, idling		◎							○					
		Lights up at low, high idling			◎	◎	◎	◎	○	○	○					○
		Lights-up on slopes							◎							
		Sometimes lights up								◎	◎		○	○		
	Crushed piping, leakage from hydraulic piping (external)											◎				
	Oil level sensor lamp lights up								◎				◎			
	When oil level in oil pan is checked, it is found to be low								◎							
	Metal particles are found when oil is drained			◎												
	Metal particles are stuck to oil filter element			◎				○								
	Oil is cloudy white or smells of diesel oil														◎	
Troubleshooting	When oil filter is inspected directly, it is found to be clogged		●	●												
	Remove oil pan and inspect directly				●	●	●									
	Oil pump rotation is heavy, there is play							●								
	There is catching of relief valve, regulator valve, or spring, valve guide is broken									●	●					
	When oil level sensor is replaced, oil pressure sensor lamp goes out												●			
	When oil pressure is measured, it is found to be within standard value													●		
	Check oil cooler														Carry Troubleshooting for "Oil level rises"	●
Remedy			Clean	Clean	Clean	Clean	Repair	Replace	Add	Adjust	Adjust	Repair	Replace	Replace	I	Replace

Legend

○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-13 Oil level rises

★ If there is oil in the cooling water, carry out troubleshooting for “Oil is in cooling water”

General causes why oil level rises

- Water in oil (cloudy white)
- Fuel in oil (diluted, and smells of diesel fuel)
- Entry of oil from other component

		Causes												
		Broken oil cooler core, O-ring	Defective nozzle holder sleeve	Broken cylinder head, head gasket (including precombustion chamber)	Clogged water pump breather hole, defective seal	Worn, damaged rear seal surface	Defective seal of pump or auxiliary equipment	Leakage of fuel from zozzle holder retaining cap	Defective inside injection pump	Defective thermostat seat	Damaged cylinder liner O-ring, holes made by pitting	Cracks inside cylinder block	Broken after-cooler core
Questions	Confirm recent repair history												
	Degree of use / Operated for long period		Δ		Δ	Δ	Δ				Δ		
	There is oil in radistor cooling water	◎	○	○							○	○	
Check items	Exhaust gas is white		◎					○		○			
	When engine is first started, drops of water come from muffler		◎										○
	Leave radiator cap open. when engine is run at idling, an abnormal number of bubbles appear, or water spurts back			◎							○		
	Water pump breather hole is clogged with mud				◎								
	When water pump breather hole is cleaned, water comes out				◎								
	Oil level does down in TORQFLOW transmission, or damper case					◎							
	Oil level does down in hydraulic tank						◎						
	Engine oil smells of diesel fuel							◎	◎	◎			
	Fuel is added more frequently							◎	◎	◎			
Troubleshooting	Pressure-tightness test of oil cooler shows there is leakage	●											
	Pressure-tightness test of cylinder head shows there is leakage		●										
	When compression pressure is measured, it is found to be low			●									
	Remove water pump and inspect directly				●								
	Inspect rear seal directly					●							
	When pump auxiliary equipment is removed, seal is found to be broken						●						
	Remove nozzle holder and inspect directly							●					
	Remove injection pump and inspect directly								●				
	There is improper contact of thermostat seat vavle									●			
	Remove oil pan and inspect directly										●	●	
	Pressure-tightness test of after-cooler core shows there is leakage												●
	Remedy	Replace	Replace	Replace	Replace	Repair	Replace	Repair	Replace	Repair	Replace	Replace	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-14 Water temperature becomes too high (overheating)

General causes why water temperature becomes too high

- Lack of cooling wind (deformation, damage of fan)
- Drop in heat dissipation efficiency
- Defective cooling circulation system
- Rise in oil temperature of power train

★ Carry out trubleshooting for chassis

			Causes															
			Broken water pump	Clogged, crushed radiator fin	Clogged radiator core, leakage	Defective thermostat (does not open)	Defective water temperature gauge	Insufficient cooling water	Fan belt slipping, worn fan pulley	Clogged, broken oil cooler	Defective pressure valve	Broken cylinder head, head gasket	Damaged cylinder liner O-ring, holes made by pitting	Rise in torque converter oil temperature	Crack in cylinder block	Defective fan pump motor (BD457A-1)
Questions	Confirm recent repair history																	
	Degree of use	Operated for long period		Δ	Δ							Δ	Δ					
	Condition of overheating	Suddenly overhated	◎					○	○									
		Always tends to overheat		◎	◎	○			○									◎
	Water temperature gauge	Rises quickly				◎		○										
		Does not go down from red range					◎											
	Radiator water level sensor lights up							◎										
Check items	Fan belt whines under sudden load								◎									
	Cloudy white oil is floating on cooling water									◎								
	Cooling water flows out from overflow hose										◎							
	Excessive air bubbles inside radiator, water spurts back											◎						
	Engine oil level has risen, oil is cloudy white									○			◎		◎			
	Radiator shroud, inside of underguard are clogged with dirt or mud			◎					◎									
	When light bulb is held behind radiator, no light passes through			◎														
	Water is leaking because of cracks in hose or loose clamps							◎										
	Belt tension is found to be slack								◎									
	Power train oil temperature enters red range before engine water temperature													◎				
Troubleshooting	Temperature difference between top and bottom radiator tanks is excessive		●											Carry out troubleshooting for chassis				
	Temperature difference between top and bottom radiator tanks is too small			●														
	When radiator is inspected through water filler port, the core is found to be clogged				●													
	When a function test is carried out on the thermostat, it does not open at the cracking temperature					●												
	When water temperature is measured, it is found to be normal						●											
	When oil cooler is inspected directly, it is found to be clogged									●								
	When measurement is made with radiator cap tester, set pressure is found to be low										●							
	When compression pressure is measured, it is found to be low											●						
	Remove oil pan and inspect directly												●		●			
	Pressure-tightness test of cylinder head shows there is leakage											●						
	Remedy		Replace	Repair	Repair	Replace	Replace	Add	Repair	Replace	Replace	Replace	Replace	I	Replace	I		

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-15 Abnormal noise is made

★ Judge if the noise is an internal noise or an external noise

General causes why abnormal noise is made

- Abnormal due to defective parts
- Abnormal combustion noise
- Air sucked in from intake system

			Causes															
			Worn piston ring, cylinder liner	Seized turbocharger, interference	Missing, seized bushing	Clogged, seized injection nozzle	Defective injection pump (rack, plunger seized)	Defective injection pump (excessive injection)	Deformed fan, interference of fan belt	Improper adjustment of valve clearance	Broken valve system (valve, rocker lever, etc.)	Improper gear train backlash	Leakage of air between turbocharger and cylinder head	Defect inside muffler (dividing board out of position)	Leakage from air compressor piping	Seized crankshaft, bearing
Questions	Confirm recent repair history																	
	Degree of use	Operated for long period	Δ															
	Condition of abnormal noise	Gradually occurred	○						○									
		Suddenly occurred		○	○						○							
	Non-specified fuel has been used					○	○											
	Engine oil must be added more frequently		◎															
	Color of exhaust gas	Blue under light load	◎															
		Black		◎						○			○					
Check items	Metal particales are found in oil filter		◎		◎													◎
	Blow-by gas is excessive		◎															
	Noise of interference is heard from around turbocharger			◎														
	Engine pickup is poor and combustion is irregular					◎												
	When exhaust manifold is touched immediately after starting engine, temperature of some cylinder is low					◎	○											
	Seal on injection pump has come off							◎										
	Abnormal noise is loud when accelerating engine					○	○	○	○	○		○			○			
	Clanging sound is heard from around cylinder head									◎	◎							
	Leakage of air between turbocharger and cylinder head												◎					
	Vibrating noise is heard from around muffler													◎				
Troubleshooting	When compression pressure is measured, it is found to be low		●															
	When turbocharger is rotated by hand, it is found to be heavy			●														
	Remove gear cover and inspect directly, (flywheel housing top cover)				●							●						
	Some cylinder does not change engine speed when operating on reduced cylinders					●												
	When control rack is pushed, it is found to be heavy or does not return						●											
	Injection pump test shows that injection amount is incorrect							●										
	Fan is deformed, or belt is loose								●									
	When valve clearance is checked directly, it is found to be outside standard value									●								
	Remove cylinder head cover and inspect directly										●							
	When muffler is removed, abnormal noise disappears													●				
	Check for leakage from air compressor piping														●			
	Remove oil pan and inspect																	●
	Remedy		Replace	Replace	Replace	Replace	Replace	Adjust	Repair	Adjust	Replace	Repair	Repair	Replace	Replace	Replace		

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

S-16 Vibration is excessive

★ If there is abnormal noise together with the vibration, carry out troubleshooting for “Abnormal noise is made”

General causes why vibration is excessive

- Defective parts (abnormal wear, breakage)
- Improper alignment
- Abnormal combustion

			Causes											
			Worn, seized connecting rod, main bearing	Worn cam bushing	Worn support pilot	Loose engine mounting bolts, broken cushion	Broken part inside output shaft (damper)	Misalignment between engine and power train	Improper gear train backlash	Valve system (valve, rocker lever, etc.) stuck	Defective injection pump (excessive injection, plunger seized)	Defective vibration damper	Clogged injection nozzle
Questions	Confirm recent repair history												
	Degree of use	Operated for long period	Δ	Δ	Δ	Δ							
	Condition of vibration	Suddenly increased					○			○		○	
		Gradually increased	○	○	○	○							○
	Non-specified fuel has been used		○	○									
Check items	Metal particales are found in oil filter		◎	◎									
	Metal particales are found when oil is drained		◎	◎									
	Oil pressure is low at low idling		○	○									
	Vibration occurs at mid-range speed					○	○						
	Vibration follows engine speed				○	○	○	○	○			○	
	Exhaust gas is black									◎	○		○
	Seal on injection pump has come off										◎		
Troubleshooting	Remove oil pan and inspect directly		●										
	Remove side cover and inspect directly			●									
	Check directly for worn support pilot, play				●								
	Inspect directly for loose engine mounting bolts, broken cushion					●							
	Check inside of output shaft (damper) directly						●						
	When radial runout, face runout are measured, they are found to be outside standard							●					
	Remove front cover, and inspect directly.								●				
	Remove head cover and inspect directly									●			●
	Injection pump test shows that injection amount is incorrect										●		
		Remedy	Replace	Replace	Replace	Replace	Replace	Repair	Repair	Replace	Adjust	Replace	Replace

Legend
○: Possible cause (judging from Questions and Check items)
◎: Most probable causes (judging from Questions and Check items)
Δ: Possible causes due to length of use (used for a long period)
●: Items confirm the cause

ENGINE

14 DISASSEMBLY AND ASSEMBLY

★ The explanation for disassembly and assembly of the engine given in this section describes the procedure for the BSA6D170-1 engine when using the repair stand.

★ If a different engine or engine repair stand is used, or if the engine is not equipped with an aftercooler, the procedure may be different in places, but the operation is basically the same.

DISASSEMBLY

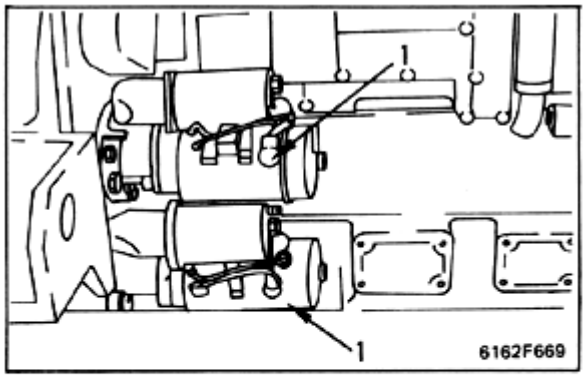
Special tools

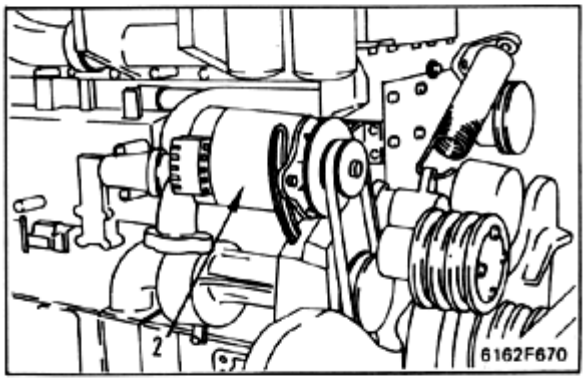
No.	Part No.	Part Name	Qty
A	790-501-2000	Engine repair stand	1
A1	790-901-1170	• Repair stand bracket	1
B	790-476-1140	Lifting tool	1
C	795-601-1110	push tool	1
D	795-102-2102	Spring pusher	1
E	795-100-1181	Timer remover	1
F	795-100-1191	Piston ring tool	1
G	795-102-1300	Liner puller	1

• Preparatory work

1. Washing

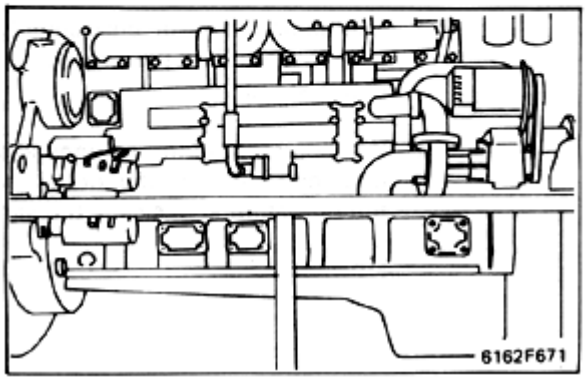
- Before disassembling the engine, check all parts for any cracks of damage, then clean the whole engine carefully with steam so that the disassembly work can be carried out swiftly.
  1) Before washing, remove starting motor assembly (1), alternator assembly (2), and electric wiring.
  2) Cover all the openings of the engine with tape.
  3) Using a washing machine, clean engine.





2. Setting engine stand

- Prepare a stable engine stand that will prevent the engine from falling over, then set the engine assembly on the stand and secure it in position.



3. Engine oil

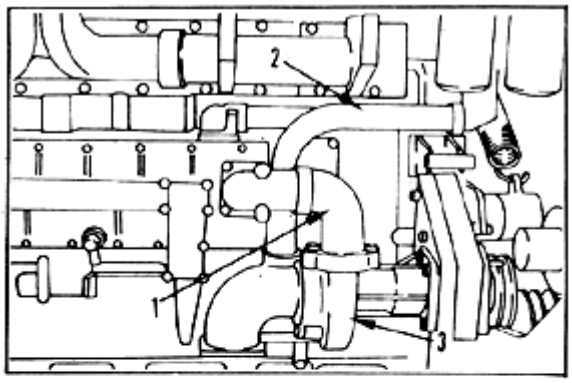
Drain engine oil

Engine oil : Approx. 41 liter

1. Water pump assembly

1) Remove water tube (1).
2) Remove plate, then remove water tube (2).
3) Remove water pump assembly (3).

★ After removing the water pump, remove the drive shaft.

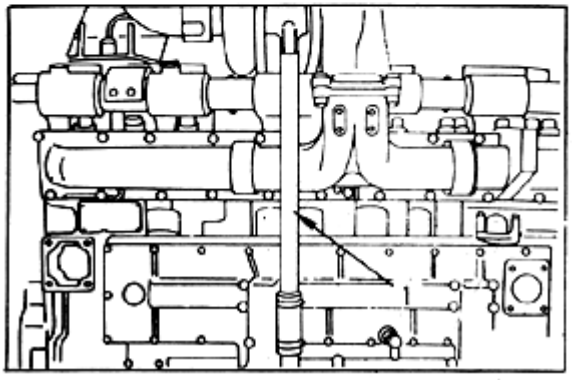


2. Turbocharger drain tube

Disconnect drain tube (1).

3. Oil cooler

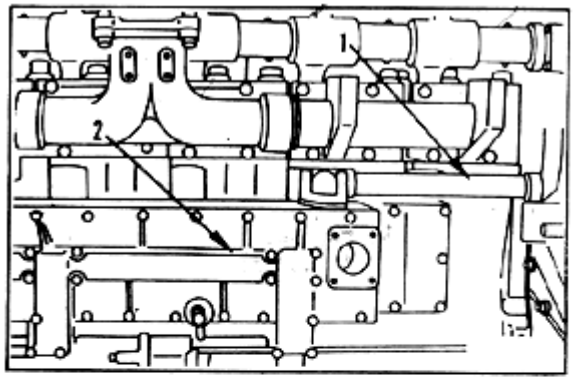
1) Remove water tube (1).
2) Remove oil cooler (2).

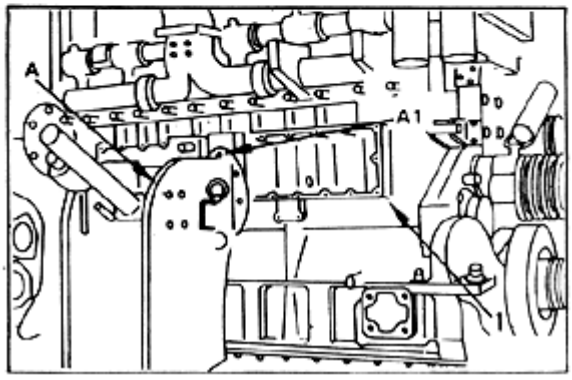


4. Placing engine on the stand

1) Install bracket **A1** for the engine repair stand **A** using the threads for the oil cooler.
2) Raise engine assembly (1) and set it to the engine repair stand **A.**

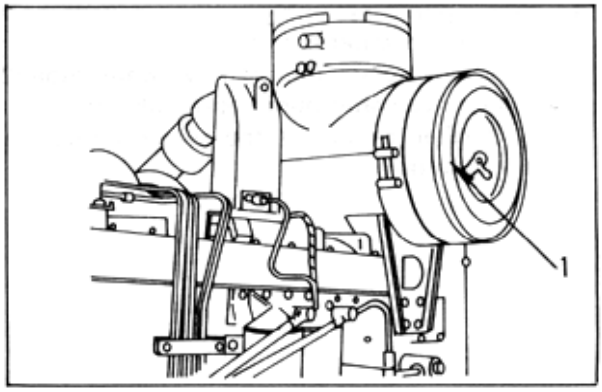
★ Tighten the bolts on the engine repair stand securely.





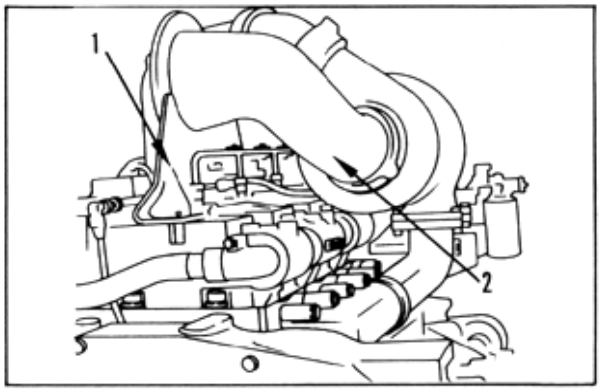
5. Air cleaner

Remove air cleaner (1).



6. Intake connector

Remove bracket (1) and intake connector (2).

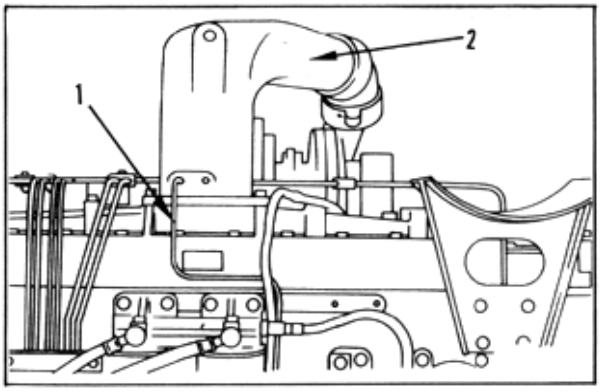


7. Connector pipe

1) Remove boost compensator tube (1).
2) Remove plate, then remove connector pipe (2).

8. Fuel filter

1) Disconnect fuel hose for APS.
2) Disconnect fuel hoses and remove fuel filter.

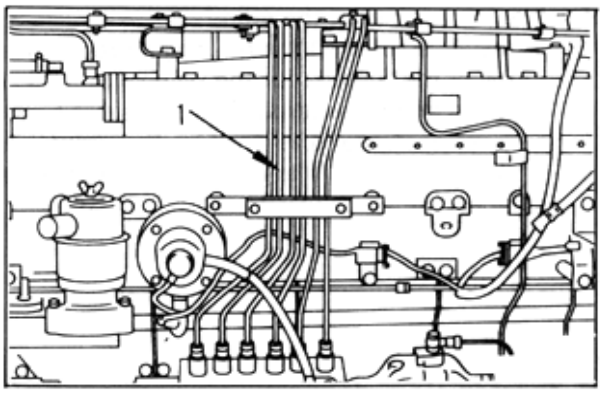


9. After-cooler tube, lubrication tube

1) Disconnect after-cooler tube.
2) Disconnect turbocharger lubrication tube.

10. Fuel injection tube

Remove lamp, and disconnect fuel injection tube (1).

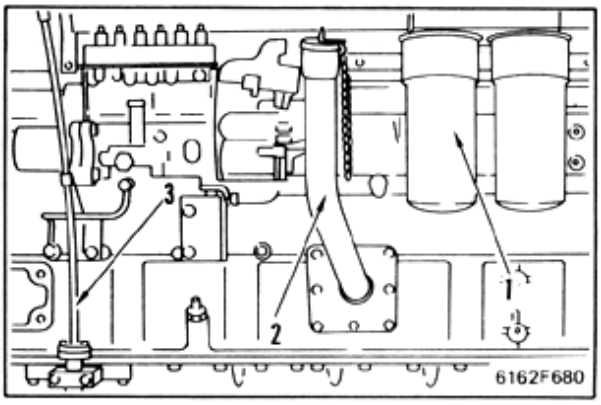


11. Oil filter

Remove oil filter (1), then remove bracket.

12. Oil filler, oil level gauge

1) Remove oil filler (2).
2) Remove oil level gauge (3).

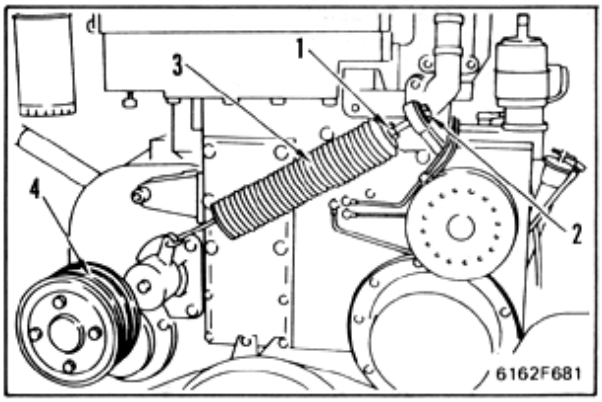


10. Tension spring, tension pulley

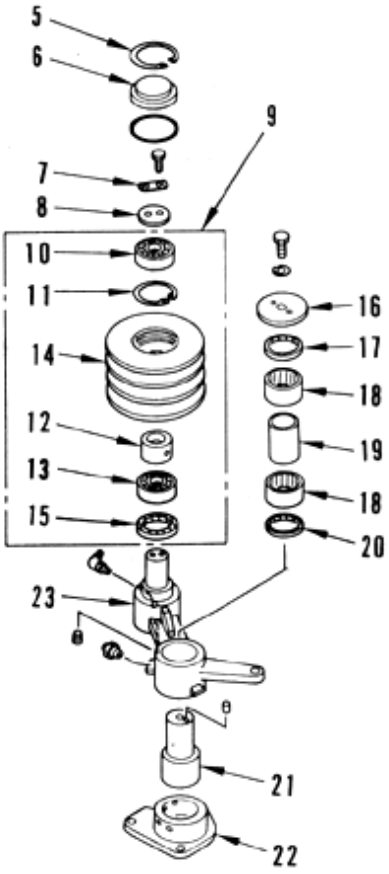
1) Loosen locknut (1), loosen bolt (2) to allow spring to expand, then remove tension spring (3).

⚠ Be careful not to get your fingers caught in the bracket.

2) Remove tension pulley assembly (4) and bracket as one unit.

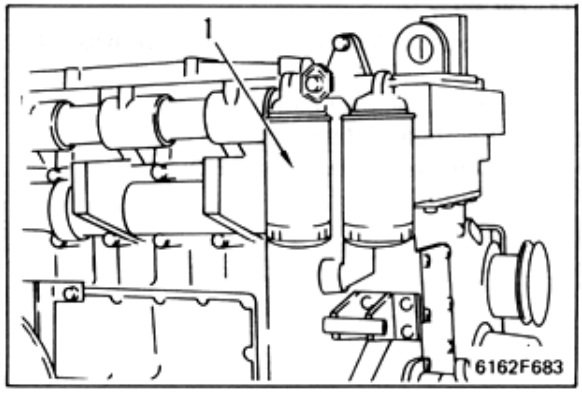


- Disassemble tension pulley assembly.
  - i) Remove snap ring (5), then remove cover (6).
  - ii) Remove lock plate (7), then remove holder (8).
  - iii) Remove pulley assembly (9) from shaft.
  - iv) Remove bearing (10), then remove snap ring (11), and take out spacer (12) and bearing (13).
  - v) Remove oil seal (15) from pulley (14).
  - vi) Remove plate (16), then remove seal (17), bearing (18), inner race (19), and seal (20).



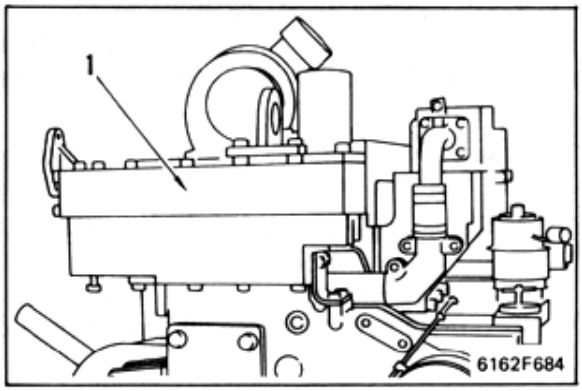
14. Corrosion resistor

Using filter wrench, remove corrosion resistors (1).

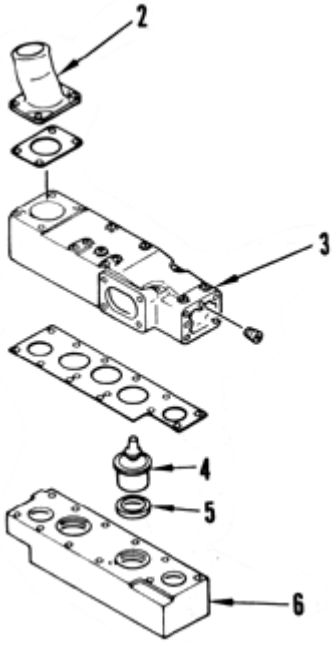


15. Thermostat housing

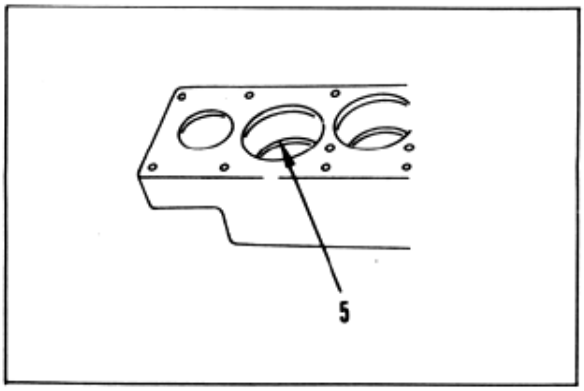
Remove thermostat housing (1).



- Disassembly thermostat housing.

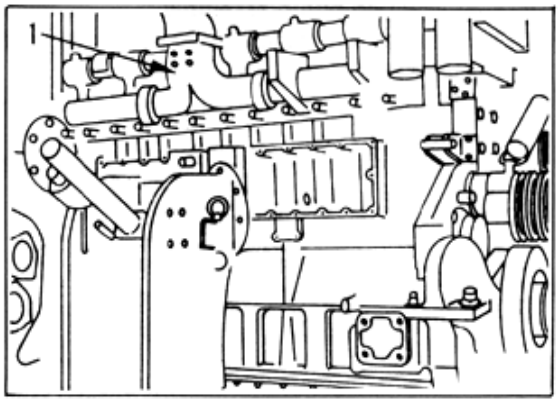


i) Remove outlet pipe (2) and cover (3).
ii) Remvoe thermostat (4).
iii) Remove thermostat seal (5) from housing (6).



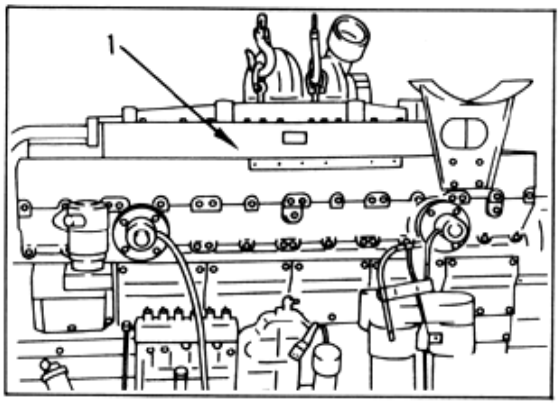
16. Turbocharger, exhaust manifold assembly

1) Sling turbocharger and exhaustmanifold assembly (1), remove mounting bolts.
2) Remove turbocharger and exhaust manifold.

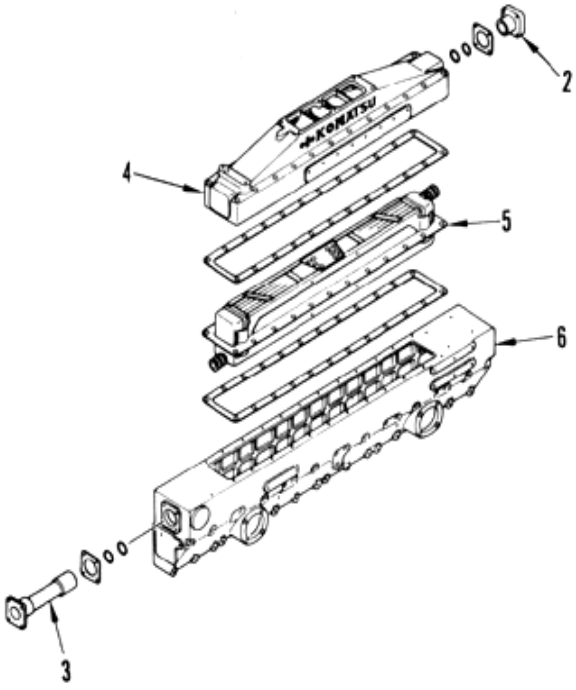


17. Aftercooler, intake manifold assembly

1) Sling aftercooler and intake manifold assembly (1), remove mounting bolts.
2) Remove aftercooler and intake manifold assembly.

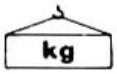


- Disassembly aftercooler and intake manifold.
  - i) Remove joint (2) and connector (3).
  - ii) Remove cover (4).
  - iii) Remove core assembly (5) from intake maniflod (6).

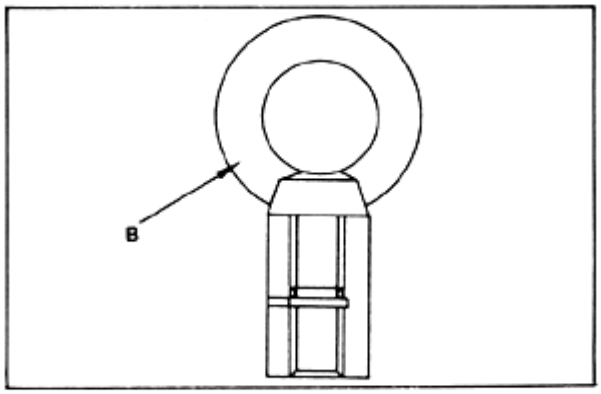


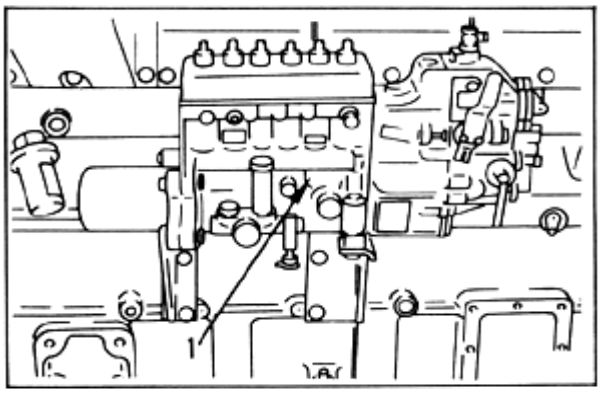
18. Fuel injection pump assembly

1) Remove lubrication tube between injection pump and cylinder block.
2) Screw lifting tool **B** into delivery valve thread, and sling assembly.
3) Pull out fuel injection pump assembly (1) to rear and remove.



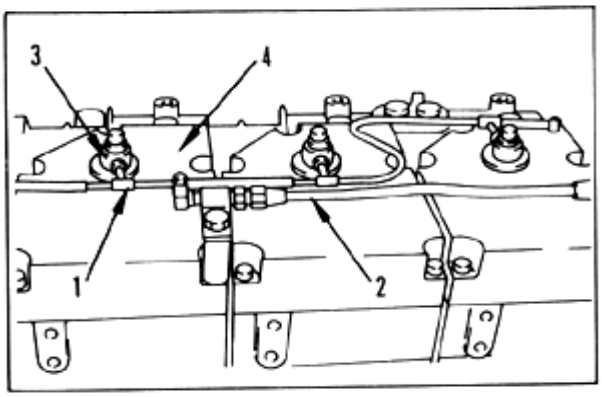
Fuel injection pump assembly.
BSA6D170 : 48 Kg
BS6D170 : 30 Kg



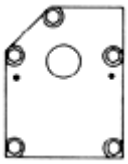


19. Spill tube, head cover

1) Disconnect spill tube (1).
2) Disconnect turbocharger lubrication tube (2).
3) Disconnect connection (3) and remove head cover (4).
   - ★ Screw forcing screws (Thread dia. = 14 mm, Pitch = 1.5 mm) into the places marked, and remvoe the head cover.
   - ★ After removing the head cover, remove the nozzle seal from the head cover.

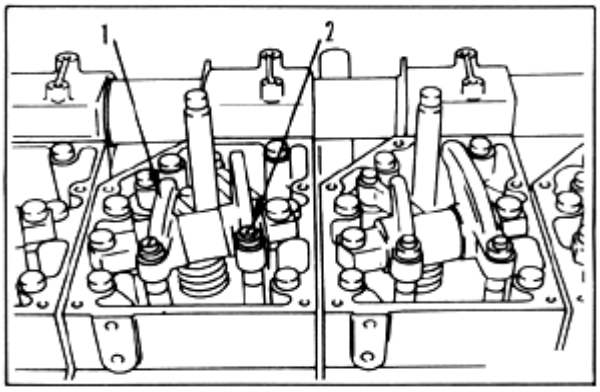


20. Rocker arm

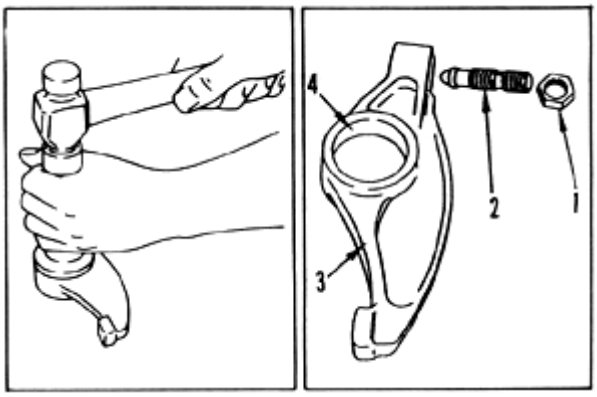


Remove rocker arm (1).

- ★ To prevent pressure on the push rod when installing, loosen the locknut and turn the adjustment screw (2) back 2 to 3 turns before removing the rocker arm assembly.

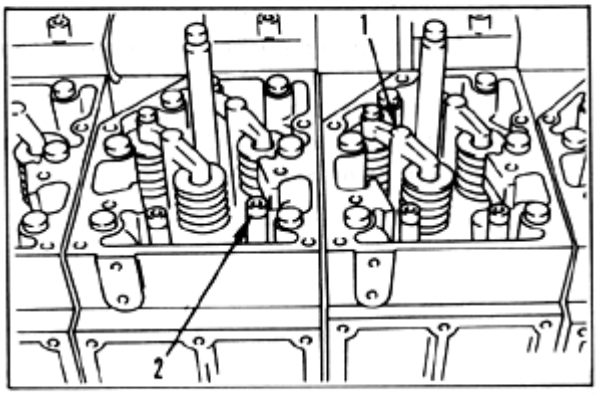


- Disassembly rocker arm assembly.
  i) Remove locknut (1), then remove adjustment screw (2) from reocker arm (3).
  ii) Using push tool, remove bushing (4).



21. Crosshead

1) Remove crosshead (1).

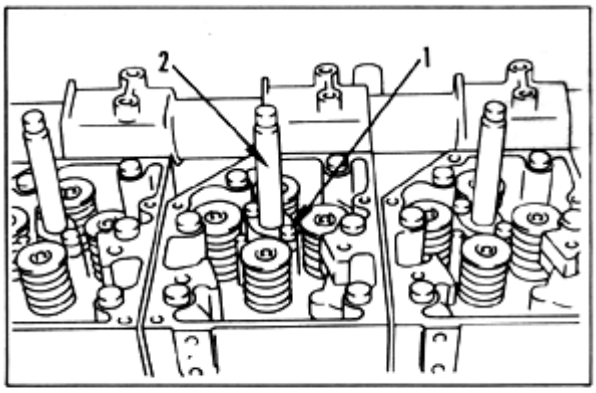


22. Push rod

Remove push rod (2).

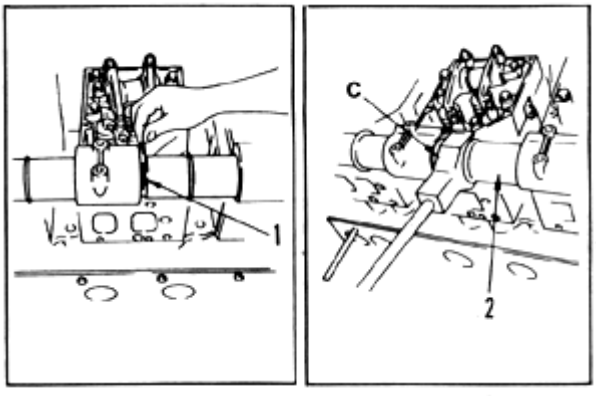
23. Injection nozzle holder

Remove mounting bolts (1), then remove injection nozzle holder assembly (2).

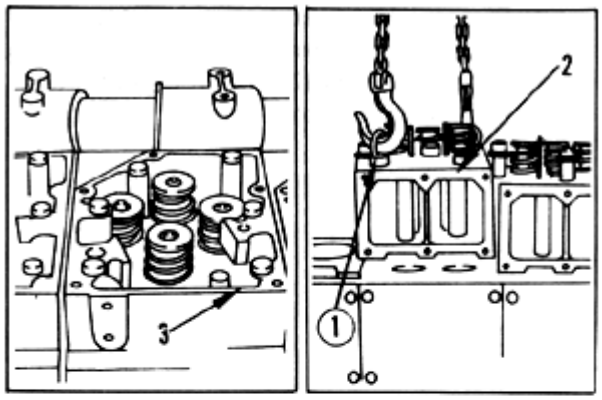


24. Rocker arm housing

1) Remove snap ring (1), then using push tool **C,** remove water manifold (2).



2) Remove rocker arm housing (3)



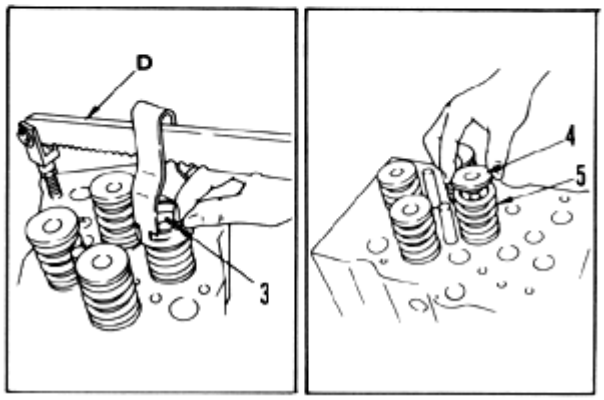
25. Cylinder head assembly

Using eyebolt 1 (Dia. = 12 mm, Pitch = 1.75 mm), remove cylinder head assembly (2).

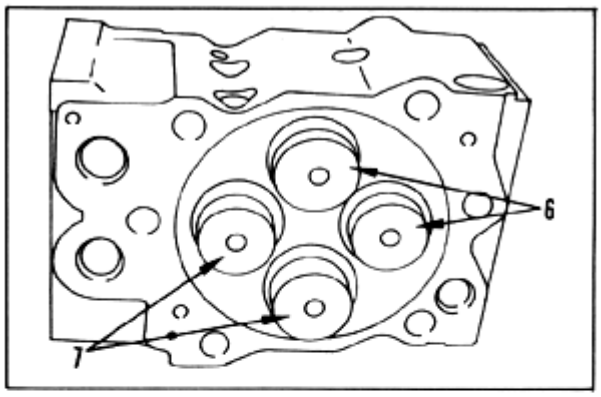
kg Cylinder head : 40 kg

- Disassembly the cylinder head

i) Using spring pusher **D**, compress spring then remove valve cotter (3).
ii) Remove retainer (4).
iii) Remove outer spring (5), inner spring and valve lower seat.

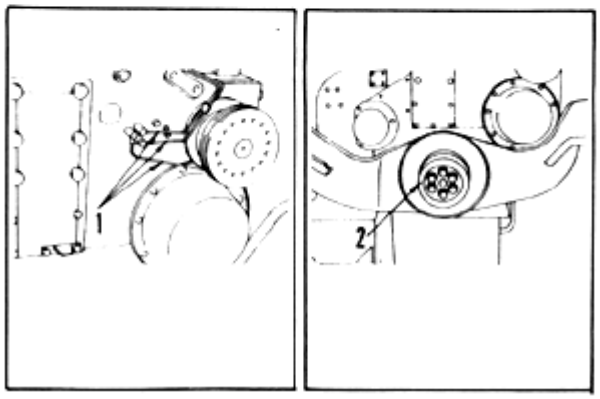


iv) Remove exhaust valves (6) and intake valves (7).



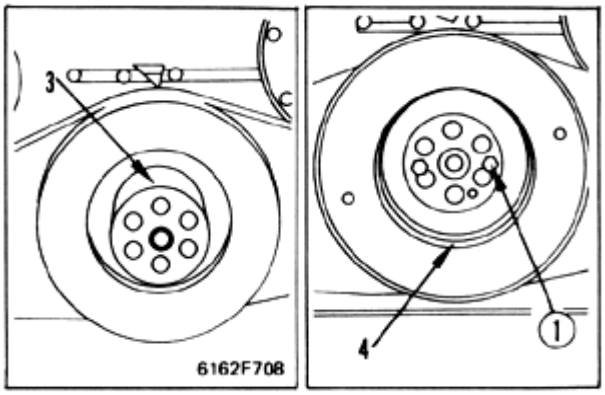
26. Crankshaft pulley

1) Remove mechanical pump tubes (1).
2) Remove crankshaft pulley (2).
   ★ If an impact wrench is used to loosen the bolts, there is danger of damage to the thread, so loosen the bolts with a hand tool.



27. Vibration dampre

1) Remove spacer (3).
2) Sling vibration damper (4), then screw in forcing screw 1 and remove vibration damper (4).
   ★ While tightening the forcing screw, take care not to drop the vibration damper.



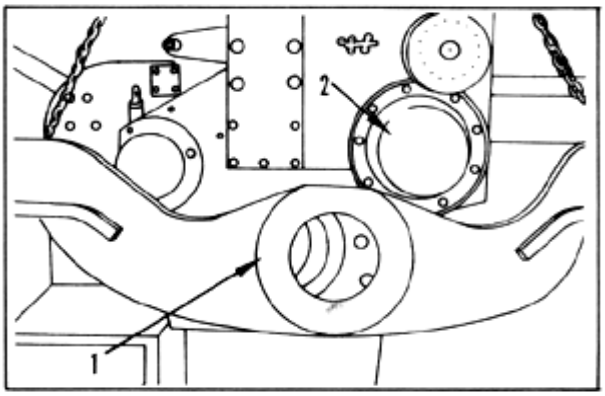
28. Front support

Lift out front support (1).

kg Front support : See Weight Table

29. Cover

Remove cover (2).



30. Trunnion

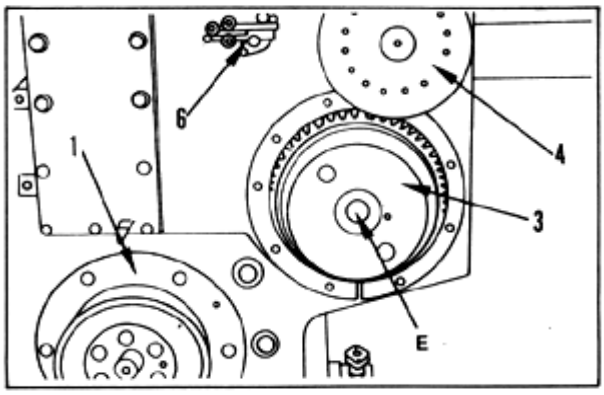
Tighten the forcing screw to remove trunnion (1).

★ When replacing the front seal, remove oil seal.

31. Timer

Using tool **E,** remove timer (3).

★ Timer (3) is press fitted with a taper, so hit the end face of reamer bar **E** with a hammer to remove it.

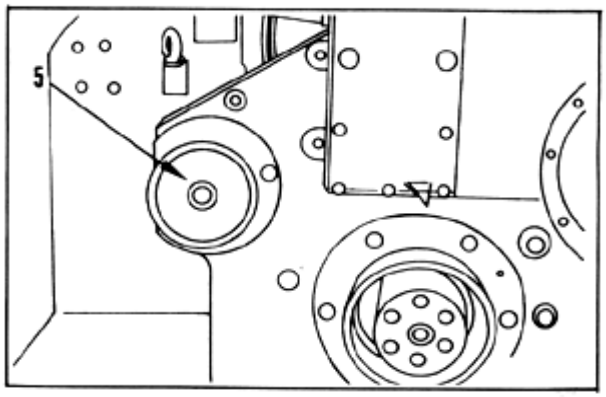


32. Accessory drive pulley

1) Remove accessory drive pulley (4).
2) Remove pulley (5) for alternator drive.

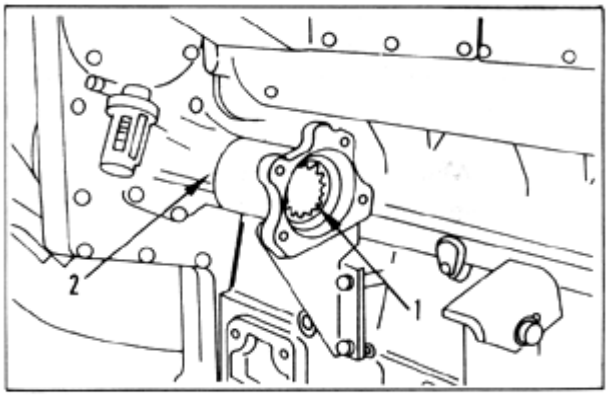
33. Mechanical pump assembly

Remove mechanical pump assembly.



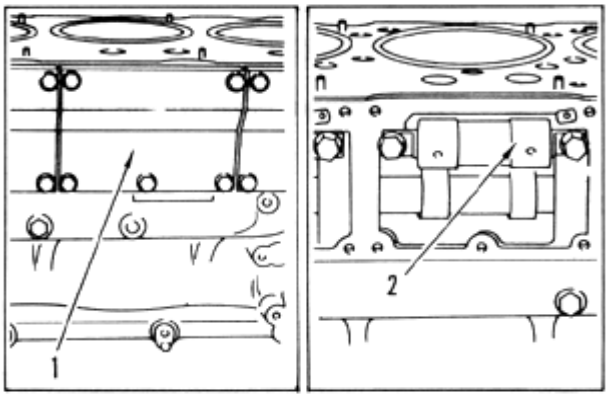
34. Injection pump drive case

Remove coupling (1), then remove injection pump drive case (2).



35. Cam follower

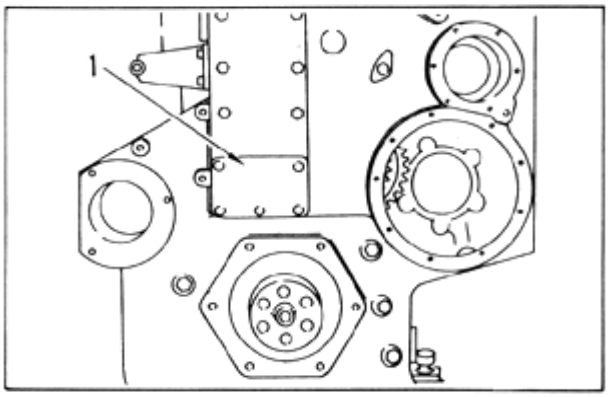
1) Remove cover (1).
2) Remove cam follower (2).



36. Gear case cover

Remove gear case cover (1).

kg Gear case cover : 48 kg

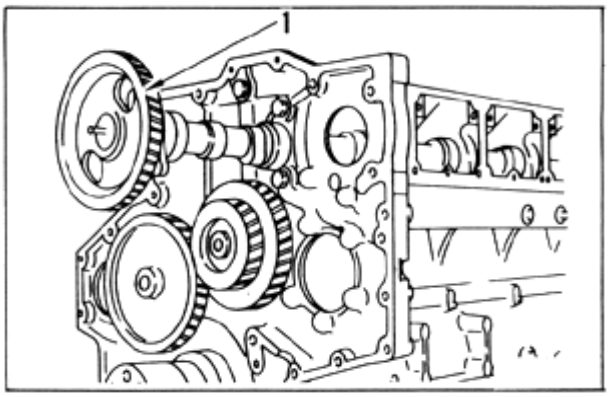


37. Camshaft assembly

Remove mounting bolt from hole in cam gear, then pull out camshaft assembly (1).

★ When removing the camshaft, rotate it while pulling it out to prevent damage to the cam bushing.

kg Camshaft assembly : 32 kg



38. Main idler gear

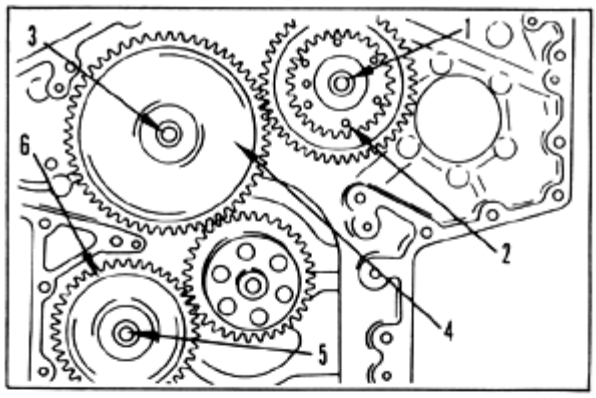
Remove mounting bolt (1), then remove main idler gear (2).

39. Idler gear for water pump gear

Remove mounting blot (3), then remove idler gear (4) for water pump.

40. Idler gear for oil pump gear

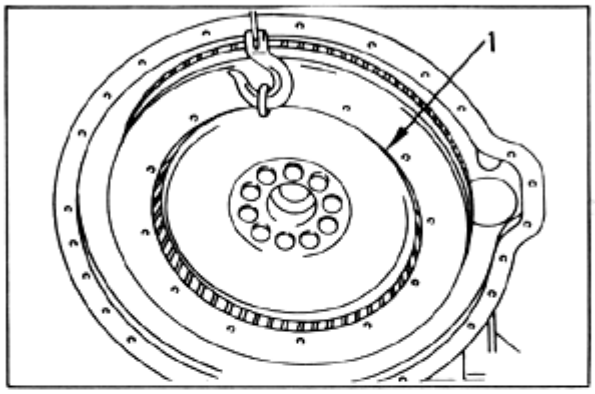
Remove mounting bolt (5), then remove idler gear (6) for oil pump



41. Flywheel

Using the sling bolts (thread dia. = 12 mm, pitch = 1.5), lift out flywheel (1).

kg Flywheel : See Weight Table

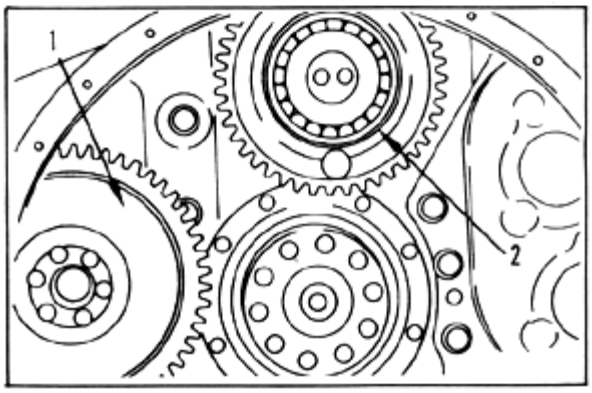


★ If an impact wrench is used to loosen the bolts, there is danger of damage to the thread, so loosen the bolts with a hand tool.

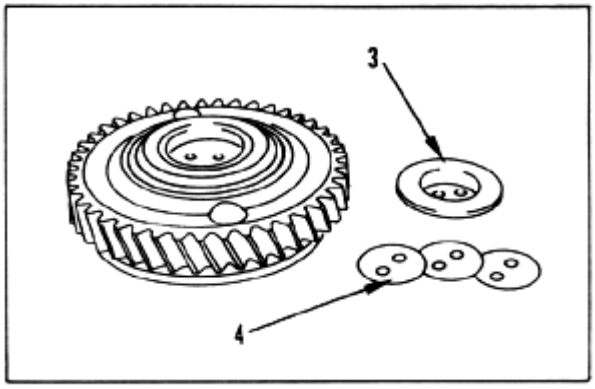
42. PTO drive gear

1) Remove steering pump drive gear (1).
2) Remove the six set bolts, and remove PTO drive gear (2).

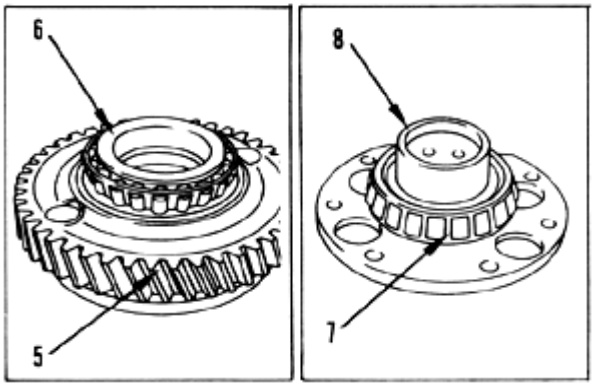
⚠ Remove 6 mounting botls while supporting the PTO drive gear by hand. If the PTO drive gear is not supported, it may fall when the bolts are removed.



- Disassemble PTO driving gear as follows:
  i) Remove bearing retainer (3) and shim(4).

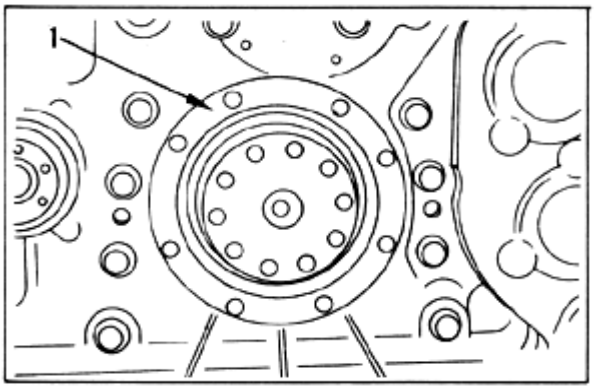


ii) Remove drive gear (5) and bearing (6).
iii) Remove bearing (7) from shaft (8).



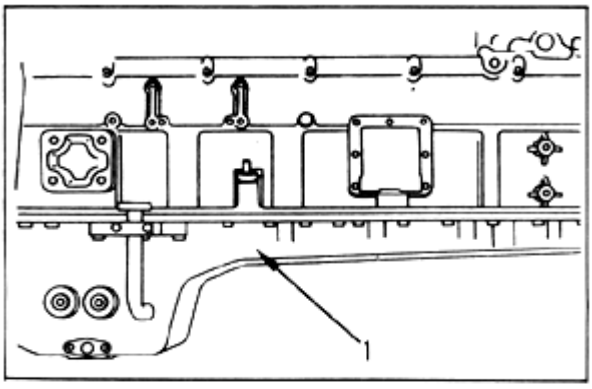
43. Rear seal cover

Remove rear seal cover (1).



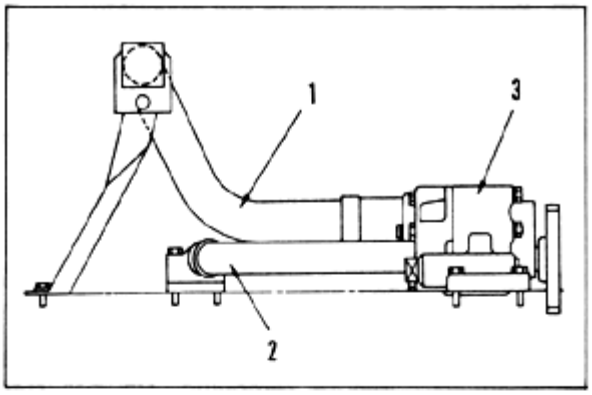
44. Oil pan

1) Turn over repair stand to set oil pan at top.
2) Remove oil pan (1).



45. Oil strainer

Remove bracket, then remove oil strainer (1).



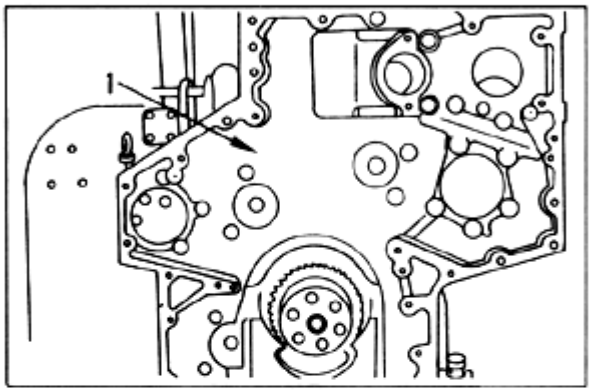
46. Oil pump assembly

1) Remove tube (2).
2) Remove oil pump assembly (3).

47. Gear case

Remove gear case (1).

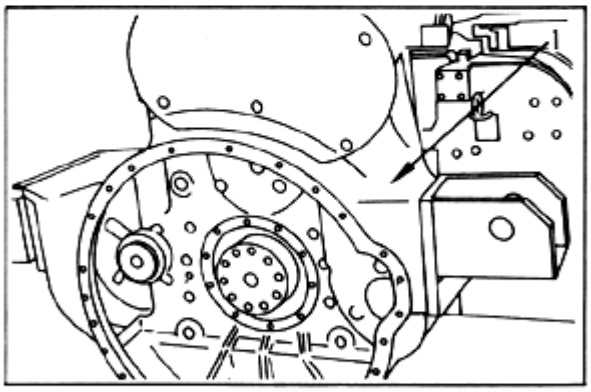
kg Gear case : 30 kg



48. Flywheel housing

Lift out flvwheel housing assembly (1).

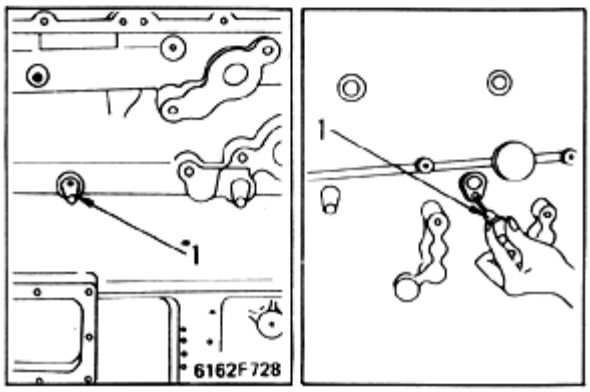
kg Flywheel housing : 95 kg



49. Piston cooling nozzle

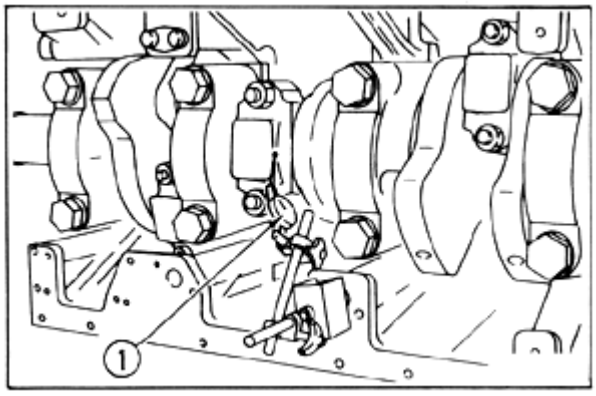
Remove piston cooling nozzle (1).

★ To avoid hitting the piston, rotate 90° to remove.



50. Piston and connecting rod assembly

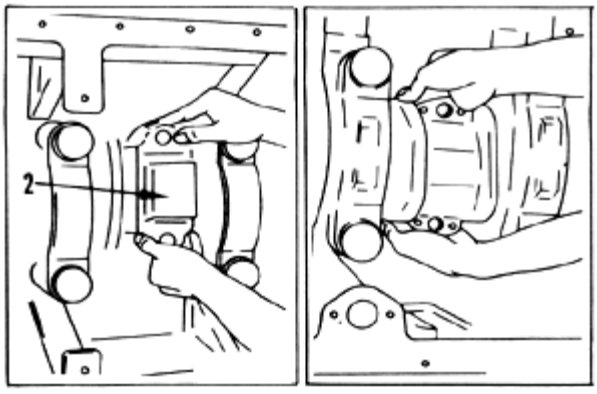
1) Using dial gauge ① measure connecting rod side clearance to act as a guide when assembling.



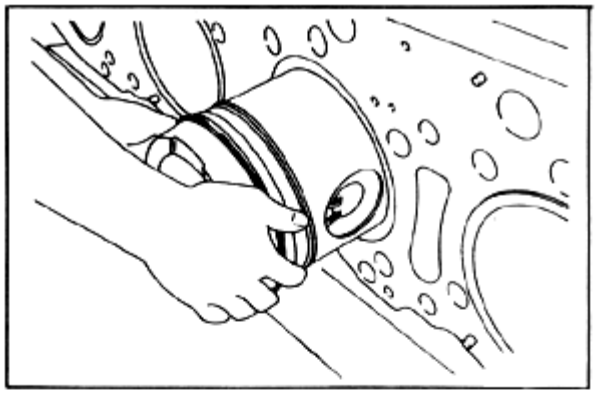
- Check the stamped number on the connecting rod cap.
  i) The cap number and cylinder number must match.
  ii) The number is stamped on the cam side.
  - ★ If there is no stamped mark, mark the cylinder No. with an electric pen before removing. Do not stamp a mark.

2) Rotate the crankshaft so that the piston to be removed is at bottom dead center.
3) Loosen connecting rod bolt 5 - 6 turns.
   - ★ If an impact wrench is used to loosen the bolts, there is danger of damage to the thread, so loosen the bolts with a hand tool.

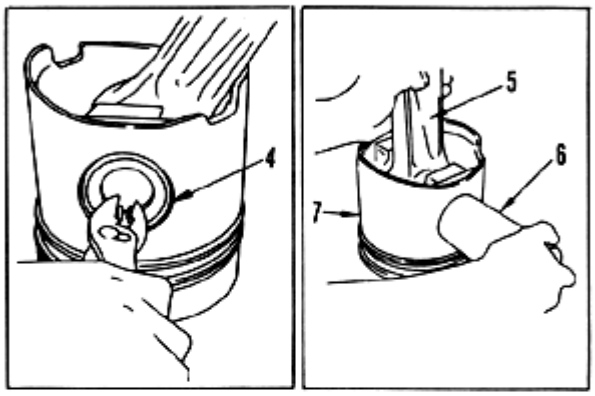
4) Tap head of connecting rod bolt with a plastic hammer, then disassemble connecting rod cap and connecting rod.
5) Remove carbon from top wall of liner with fine sandpaper.
6) Rotate crankshaft, and align with top dead center, then remove connecting rod cap (2).
7) Push in piston and connecting rod from oil pan end.

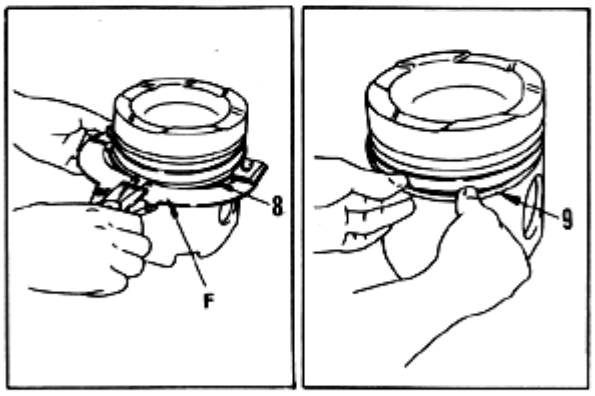


8) Support piston at cylinder head end, and remove piston and connecting rod assembly.
   ★ Be careful not to damage the inside surface of the liner with the corner of the connecting rod when removing it.
9) Remove other piston and connecting rods in the same way.
   ★ Keep in a safe place and be careful not to damage the piston sliding surface and the bearing.
   ★ Assemble the connecting rod and cap temporarily and keep together with the bearing to prevent mistakes when reassembling.



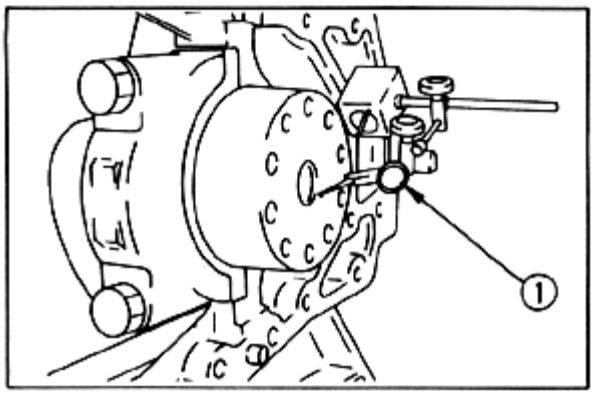
- Disassemble the piston and connecting rod assembly.
  i) Remove snap ring (4).
  ii) Support connecting rod (5) with hand, then pull out piston pin (6), and disassemble piston (7) and connecting rod.
     ★ If the piston pin is stiff and cannot be removed, heat it in hot water (100°C [212°F], 5 min.) before removing it.
  iii) Remove snap ring on the opposite side.
  iv) Using piston ring tool **F,** remove piston ring (8).
  v) Remove oil ring expander (9).
     ★ Keep the piston, connecting rod, connecting rod bearing, piston ring, and piston pin is sets for each cylinder.



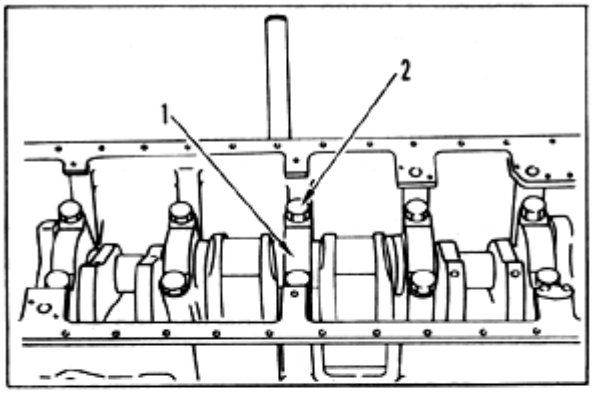


51. Crankshaft

1) Before removing the crankshaft, using dial gauge (1) to measure end play of crankshaft, and use it as a guide when assembling.
2) Measure starting torque of crankshaft and use as a guide when assembling.



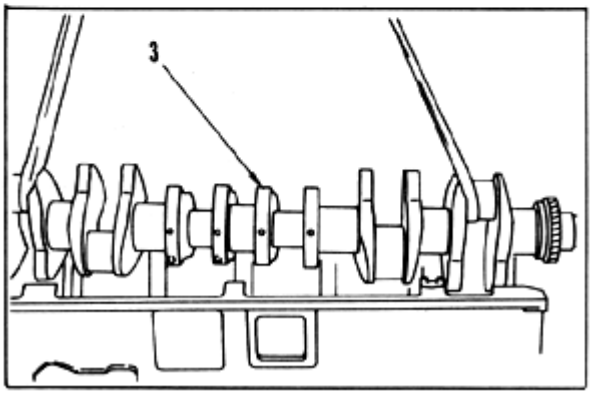
3) Remove mounting bolts(2) of main cap(1).
4) Insert bolt in hole of main cap, and move the main cap from side to side to remove it.
   ★ Thrust bearing is installed to the No. 6 cap, so after removing it, mark the assembly position.



5) Using nylon sling, lift off crankshaft (3).

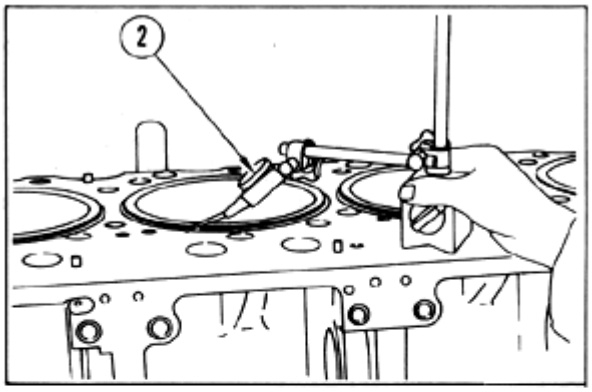
kg Crankshaft assembly : 260 kg

6) Remove upper main bearing.

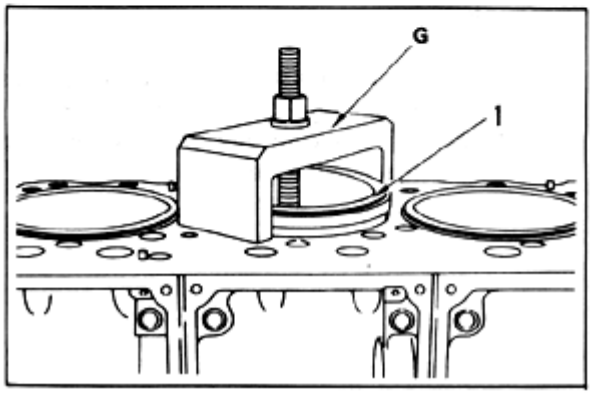


52. Cylinder liner

★ Before removing cylinder liner, using dial indicator (2) to measure protrusion of cylinder liner.



Using liner puller **G**, pull out cylinder liner (1).

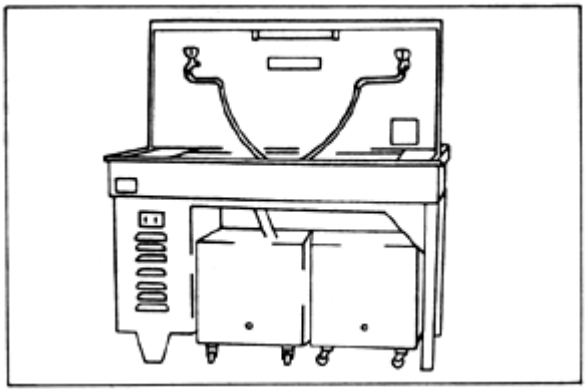


WASHING

- When washing, divide the parts into small parts and large parts, and wash the small parts in a bath like the one shown on the right.

  ⋆ Before washing disassembled parts, remove the gasket carbon with a wire brush.

  ⋆ After washing, dry the washing fluid off completely with compressed air.
  (Be particularly careful that there is no washing fluid remaining in the bolt holes.)



WASHING CYLINDER BLOCK

1) Before washing the cylinder block, remove the plugs from the oil line and cooling systems.

2) Use a washing machine such as shown on the right, and use the nozzle of a jet cleaner to wash the oil line and cooling systems thoroughly.

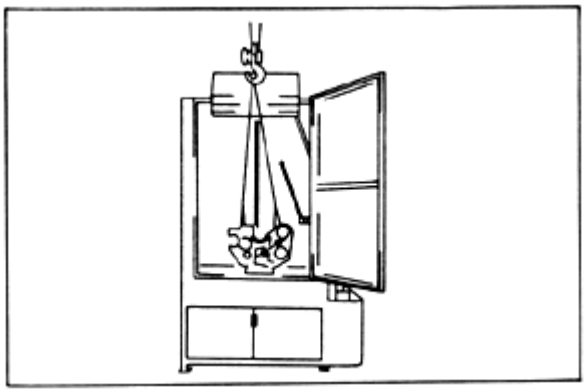
3) Clean with a stiff wire brush to prevent any metal particles from remaining in the oil line.

4) Use sandpaper to polish the O-ring contact surface smooth at the bottom of the liner bore and to remove the burrs and flashes from the liner bore.

5) Dry off the cleaning fluid completely with compressed air.

   - Be particularily careful not to leaveany cleaning fluid in the bolt holes.

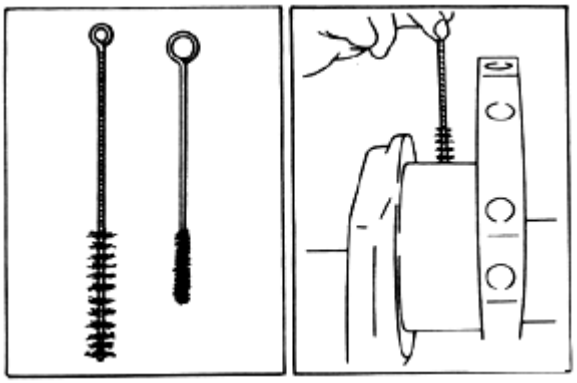
6) Completely press fit the plugs in the oil line and cooling systems.



Outside diameter of plug :
kgm Thread tightener (LT-2)

WASHING CRANKSHAFT

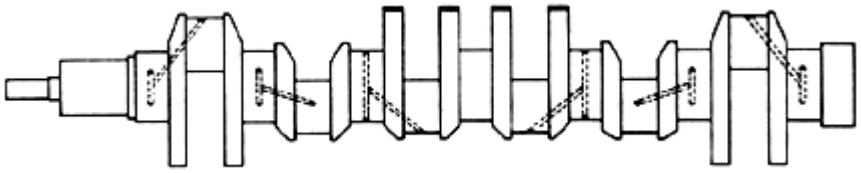
- If the engine is disassembled, wash the crankshaft before inspecting.



1) Clean the crankshaft with a steam cleaner, then use a wire brush like the one shown in the diagram on the right to clean all the oil holes.

2) After washing, dry the cleaning fluid off thorougly with compressed air.

3) Use a small magnet to completely remove all the metal particles from the oil holes.

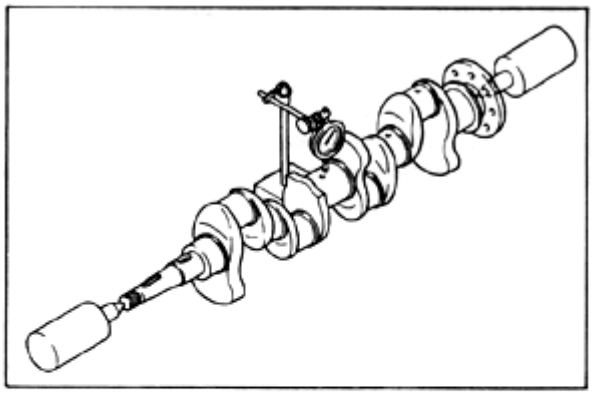


MEASURING PARTS

- Before reassembling disassembled parts, check visually that there are no cracks, damage, or abnormal wear.

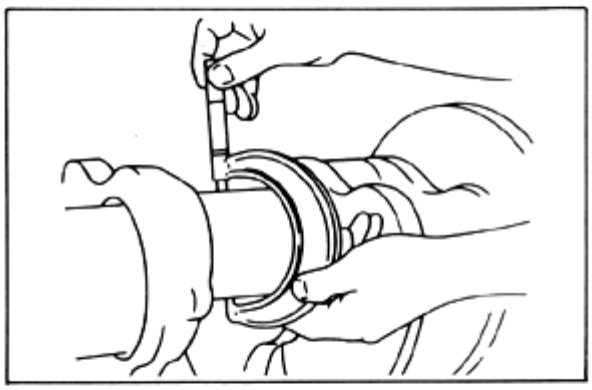
- If no abnormalities are found during the visual inspection, use an accurate measuring device to measure the specified position precisely.

- Action and judgement on whether the parts can be reused shall be in accordance with the maintenace standard.



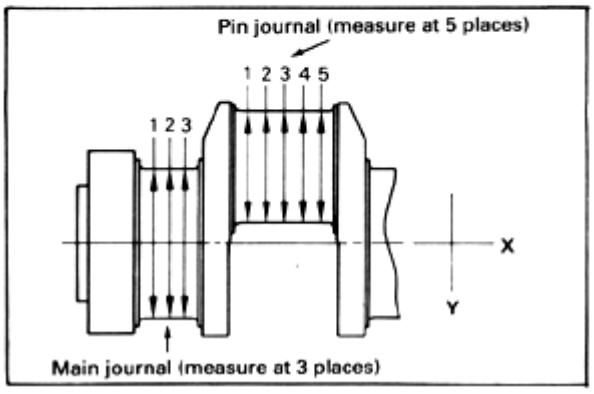
MEASURING CURVATURE OF CRANKSHFT

1) Spport the center of both ends of the crankshaft with lathes, put the indicator of the dial gauge perpendicularly in contact with the journal at the center, and set it to 0.
2) Rotate the crankshaft one turn, and measure the difference between the maximum reading and minimum reading of the dial gauge.
   ★ Do not measure with both ends of thecrank-shaft supported on V blocks. This method produces an error because of the eccentric wear of the journal.



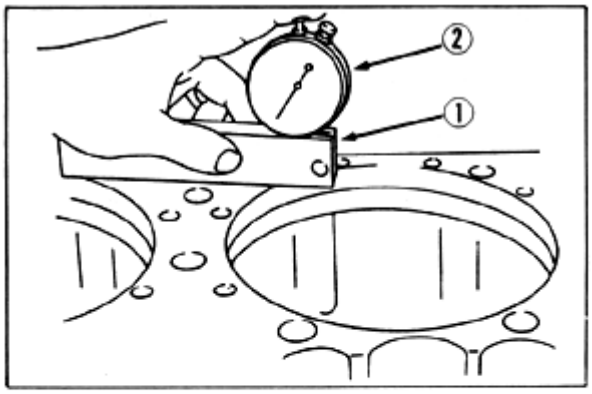
MEASURING OUTSIDE DIAMETER OF JOURNAL

1) Using a micrometer, measure the outside diam-eter of the main journal and pin journal in the X and Y directions.



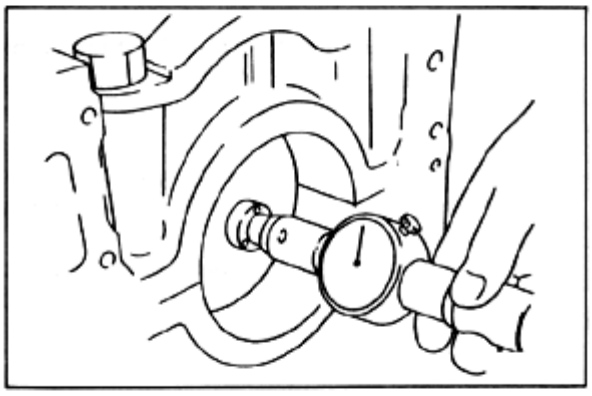
MEASURING DEPTH OF CYLINDER LINER COUNTERBORE

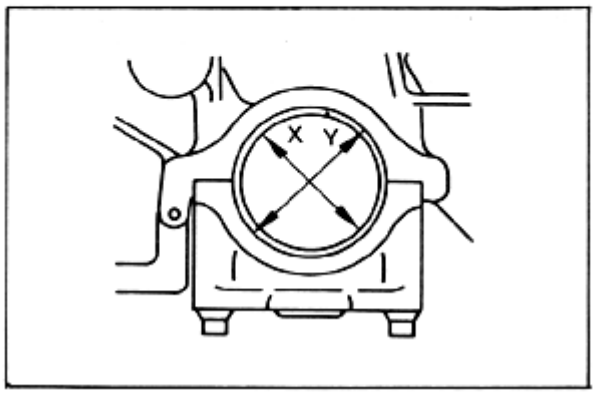
1) Set deapth gauge ② on gauge block ①, then set the gauge indicator to 0.
2) Set the gauge block parallel with the top surface of the cylinder block, and measure the depth of the counterbore.
   ★ Clean the counterbore and top surface of the cylinder block before measuring.



MEASURING MAIN BEARING BORE

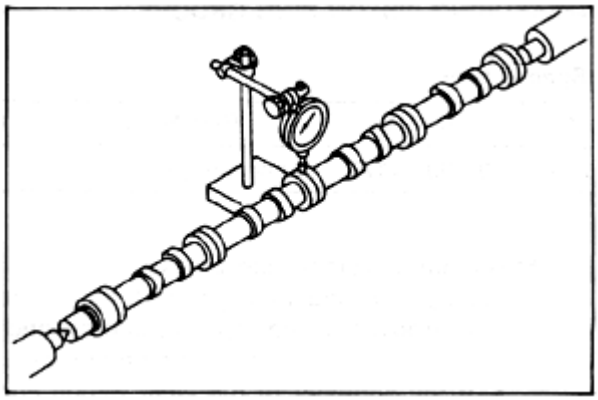
1) Install the main bearing cap to the cylinder block, and tighten to the specified torque.
2) Using a dial bore gauge or inside micrometer, measure the main bearing bore.
   ★ When measuring the bore, measure in two directions (X and Y).





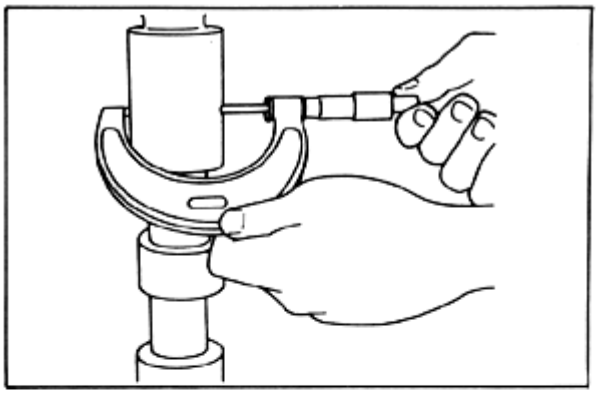
MEASURING CURVATURE OF CAMSHAFT

1) Support the center of both ends of the camshaft with lathes, put the indicator of the dial gauge perpendicularly in contact with the journal at the center and set it to 0.
2) Rotate the camshaft one turn, and measure the difference between the maximum reading and minimum reading of the dial gauge.
   - ★ Do not measure with both ends of the camshaft supported on V blocks. This method produces an error because of the eccentric wear of the journal.



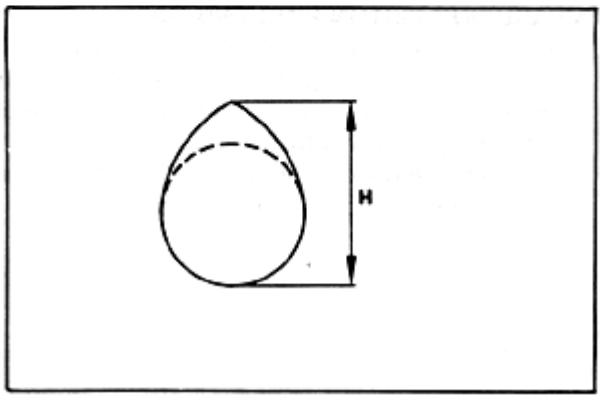
MEASURING OUTSIDE DIAMETER OF JOURNAL

1) Using a micrometer, measure the outside diameter of the journal.



MEASURING HEIGHT OF CAM

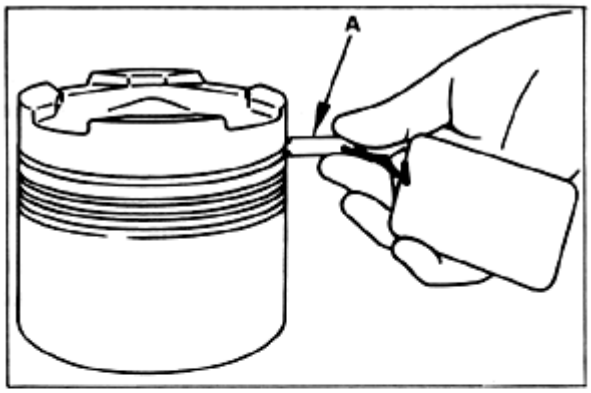
1) Using a micrometer, measure cam height **H** for the intake and exhaust.



MEASURING PISTON RING GROOVE

Special tool

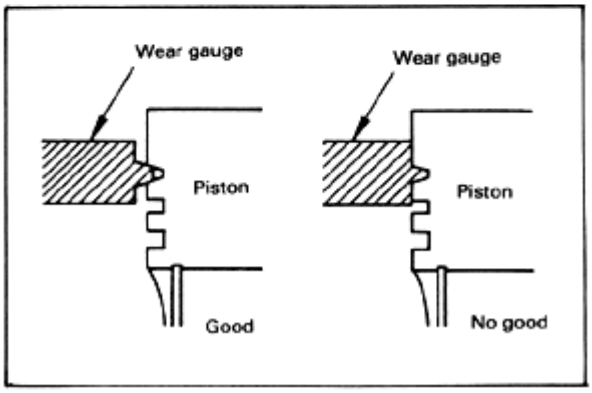
No.	Part No.	Part Name	Qty
A	795-901-1120	Wear gauge	1



- **Measuring keystone ring groove**

  1) Push piston ring wear gauge **A** lightly into the ring grooves of the top ring and second ring, and measure the wear of the ring groove.

     - If the shoulder of the wear gauge contacts the piston, replace the piston.
       ★ Carry out the measurement at several places.

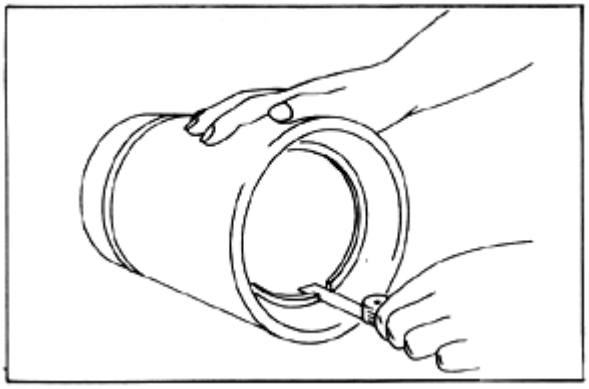


- **Measuring straight ring groove**

  1) Assemble a new ring in the oil ring groove, and measure the clearance at the top and bottom with a feeler gauge.
     ★ If the clearance is greater than the permissible limit, replace the piston.

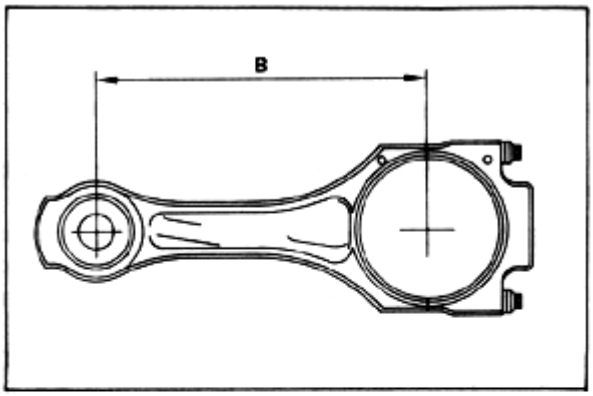
MEASURING PISTON RING END GAP

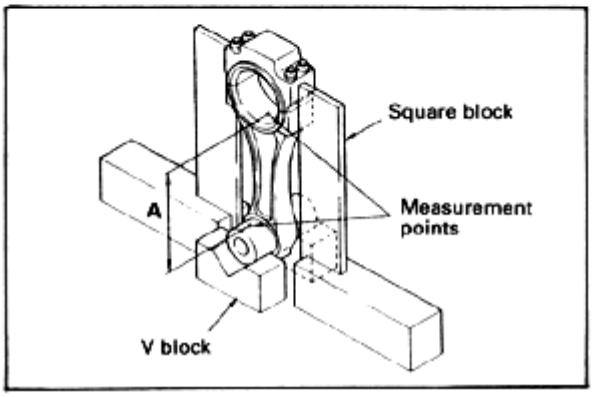
1) Assemble the piston ring to the cylinder liner, push the piston ring into the area of the cylinder where there is least wear, then measure the piston ring end gap with a feeler gauge.
   ★ Insert the piston ring so that it is at right angles to the sliding portion of the liner.



MEASURING LENGTH OF CONNECTING ROD

1) Tighten the mounting bolts of the connecting rod cap to the specified torque.
   ★ Do not assemble the connecting rod bearing.
2) Assemble a new piston pin in the hole at the small end of the connecting rod.
   ★ Coat the piston pin with grease (G2-LI) before installing.
3) Support both ends of the piston pin on V blocks, and support both ends of the connecting rod on square blocks.
4) Measure distance **A** between the big end and small end with a height gauge.
5) Measure the inside diameter of the big end and small end.

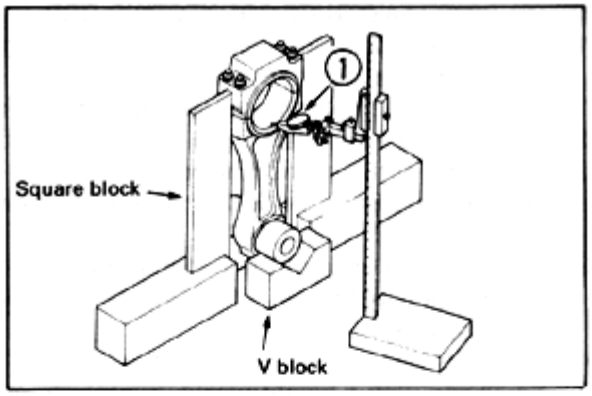




- Calculate the value for the length **B** of the connecting rod as follows.
  Connecting rod dimension **B**

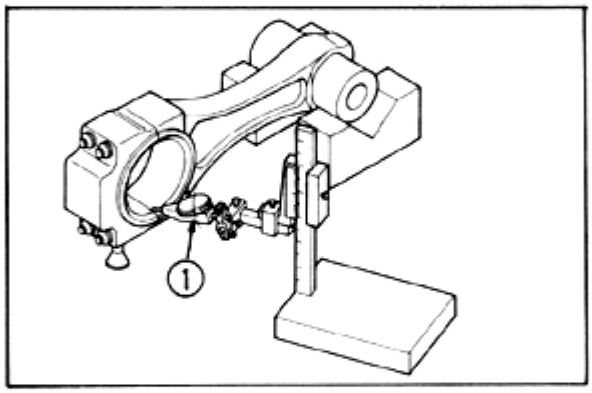
$$= \frac{\text{ID of big end + ID of small end}}{2} + \mathbf{A}$$

MEASURING CURVATURE, TWISTING OF CONNECTING ROD



- **Method for measuring curvature**

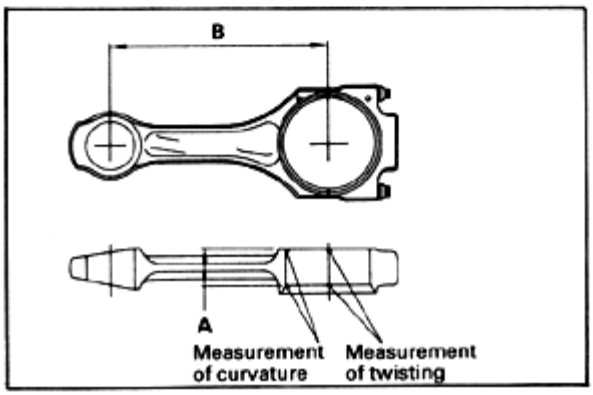
1) Tighten the mounting bolts of the connecting rod cap to the specified torque.
   ★ Do not assemble the connecting rod bearing.
2) Assemble a new piston pin in the hole at the small end of the connecting rod, place **V** blocks on a flat surface, then set both endof the piston pin on the **V** block.
   ★ Coat the piston pin with grease (G2-LI) before installing.
3) Stand the connecting rod perpendicularly, and support both sides of the big end with square blocks.
4) Set the indicator of height gauge (1) at the front of the hole at big end, set it in contact with the bottom, then set the gauge to 0.
5) Move the height gauge to the opposite side by a distance equal to the width of the big end, and read the measurement of the gauge.



- **Method of measuring twisting**

1) From the condition described above, remove the square blocks, lay the connecting rod down, and support the big end on the tip of a conical jack.

2) Measure the big end in the same way as when measuring the curvature.



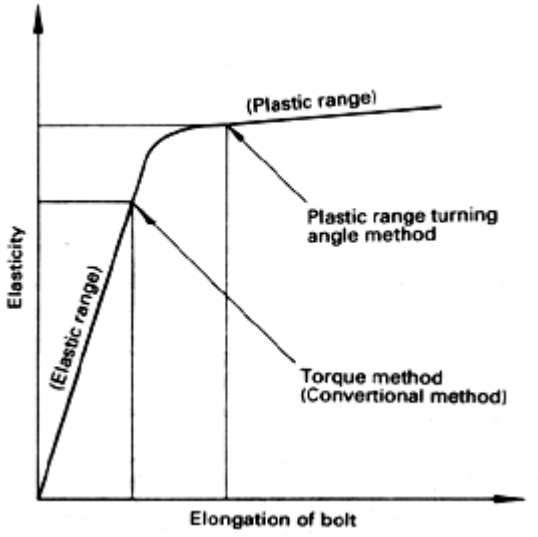
- Calcualte the value for the curvature and twisting as follows.
  Curvature, twisting

$$= \frac{\text{Dimension } \mathbf{B}}{\text{Dimension } \mathbf{A}} \times \frac{\text{Actual measured}}{\text{Value}}$$

ASSEMBLY

TIGHTENING BOLTS BY PLASTIC RANGE TURNING ANGLE METHOD

- The imported bolts on the 170 Series engine use the plastic range turning angle method for tightening.
  This method uses special bolts, and by tightening the bolts to the load where the bolt starts to deform permanently (plastic range), it is possible to get an accurate, high tightening force. (Of the methods used for tightening bolts,the method using checking of the torque is the most common, but because of the influence of friction factors, it is difficult to control the tightening force accurately.)
- The tightening method using the plastic range tuning angle method uses the initial tightening torque and the turning angle to tighten the bolts.



- Bolts tightened with the plastic range turning angle method on the 170 Series engine.
  1) Crankshaft pulley mounting bolts(Only HD465)
  2) Idler gear mouning bolts.
  3) Flywheel mounting bolts BHD465 only)

★ With the plastic range turning angle mehtod, there is a permanent deformation remaining after tightening.

Therefore, there is a limit to the number of times that the bolt can be used, so please observe the following.

1) After tightening, make one punch marks, If any bolts has more than 5 punch marks, do not use it again; replace it with a new bolt.
2) When tightening to an angle greater than the specified angle, loosen completely before tightening again. (In this case, make two punch marks.)
3) The target for the tightening angle should be the satandard value ± tolereance.

Special tools

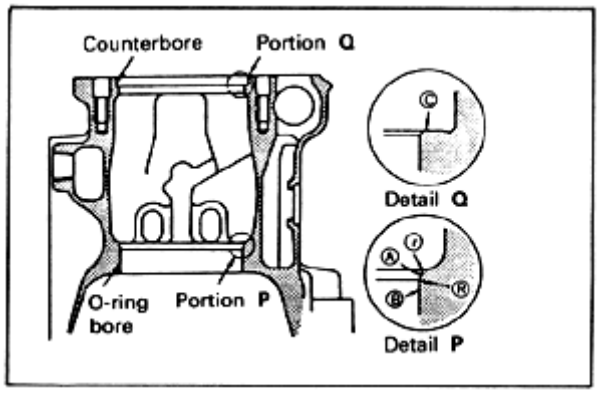
No.	Part No.	Part Name	Qty.
A	790-501-2000	Engine repair stand	1
A	790-901-1170	. Repair stand bracket	1
B	790-476-1140	Lifting tool	1
C	795-601-1110	Push tool	1
D	795-102-2102	Spring pusher	1
H	795-100-1191	Piston ring tool	1
I	795-250-1210	Liner driver	1
J	795-225-1700	Piston holder	1
K	790-331-1110	Wrench	1

- Wash all parts clean, and check that there are no dents, scratches, or casting defects. Check also that all oil or water passages are clear before as sembling.

- Before inserting the cylinder liner, take the following action with the cylinder block.

1) Remove the rust and scale from surfaces Ⓐ and Ⓑ with sandpaper unit the machining surface appears.
2) Polish portions Ⓡ and ⓡ with #240 sandpaper so that the Ⓡ surface is smooth.
3) Polish portions Ⓑ, Ⓡ and ⓡ with #240 sandpaper so that they become smooth.
   If the corner of the Ⓡ portion is sharp or there are burrs, polish with a scraper or sandpaper.
   Be sure to finish this surface particularly smoothly so that it does not scratch the O-ring.
4) If surface Ⓡ is pitted and rough, and cannot be corrected, replace the cylinder block.
5) If surface Ⓐ and portions Ⓡ and ⓡ are pitted and rough, finish them smoothly.
6) Inspect the counterbore,and remove any burrs or flashes. If there are any metal particles or dirt on surface Ⓒ, the liner will not fit properly in close contact, and this may cause problems such as leakage of water or protrusion of liner.

★ If there is any drooping, corrosion, or pitting left in the counterbore, carry out additional machining.



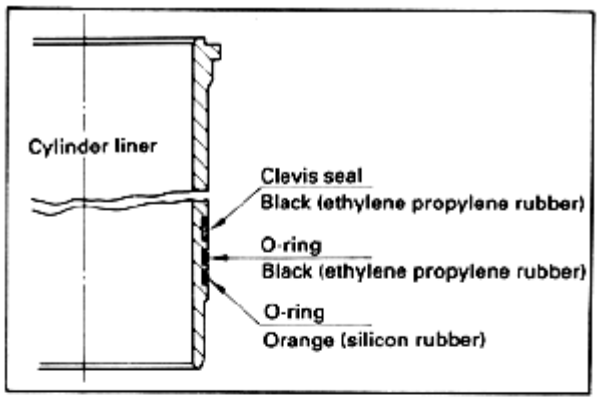
1. Cylinder liner

★ Replace the liner O-ring and clevis seal with new parts immediately before assembling the liner.

● Method of installing liner O-ring and clevis seat

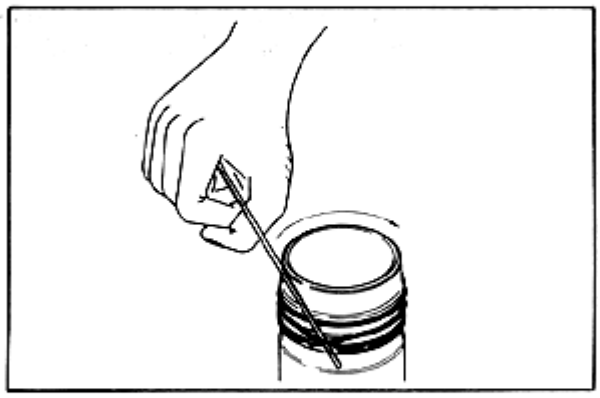
1) Check the cylinder liner O-ring groove and outside circumference of the liner to confirm that there is no rust or pitting.
   - If the surface is rough and pitted, it may cause, leakage of water, so replace the liner.

2) Coat the liner O-ring and clevis seal with clean engine oil (SAE #30).
   ★ Oil causes the clevis seal and O-ring swell and deteriorate, so do not leave them soaking in oil.
   Use a brush and coat them with a small amount of oil immediatly before assembly.



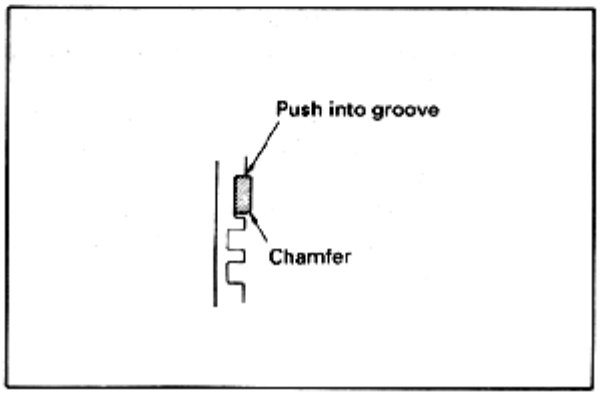
3) Assemble the liner O-ring and clevis seal to the liner as shown in the diagram on the right.

4) After installing the liner O-ring, check for twisting. If any twisting is found, use a smooth bar (approx. Ø10) to remove the twisting.

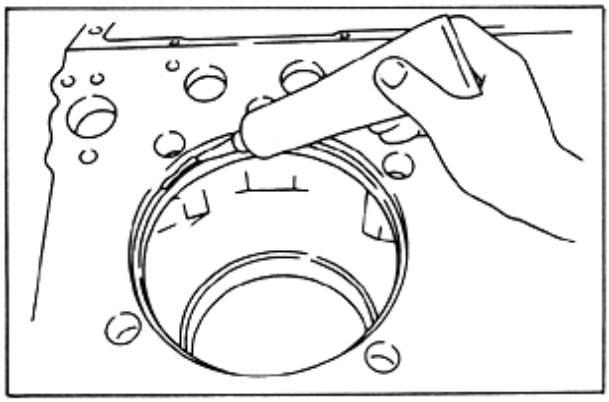


★ To prevent the clevis seal from twisting when it is installed, press it around the whole circumference so that it fits into the seal groove.

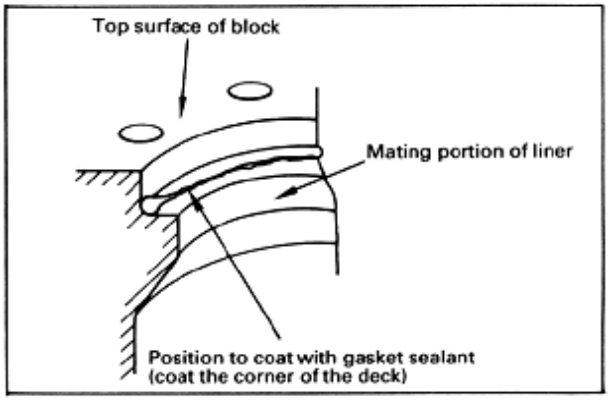
★ Assemble the clevis seal with the chamfered sidee facing down.



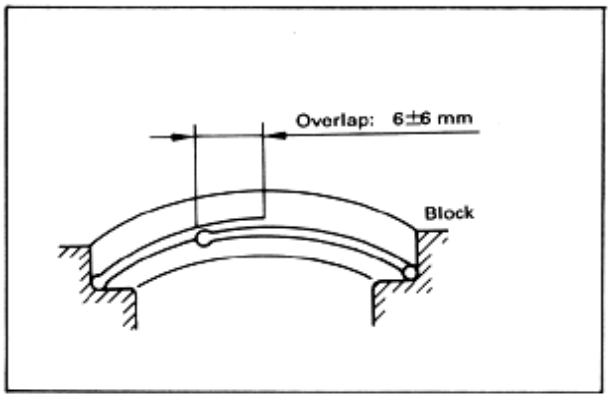
5) Method of inserting cylinder liner
   i) Using a cloth, wipe off all the dirt and oil from the contact surface of the liner lip and the cylinder block counterbore.
   ii) Coat the mating surface of the cylinder block and cylinder liner counterbore with silicon-based gasket sealant (LG-6).



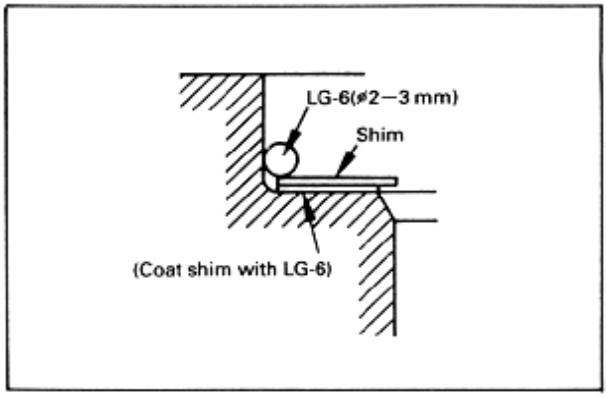
★ Width of gasket sealant : ø2.0 - 3.0 mm



★ Make an overlap of 6 ± 6 mm at the begin ning and end when coating with gasket sealant LG-6.

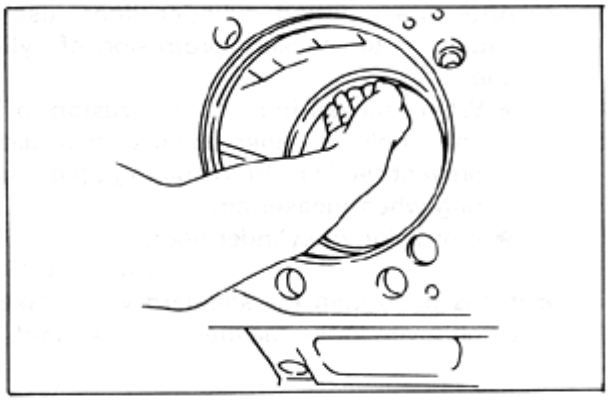


● When machining the bottom contact surface of the counterbore liner lip and using a shim.
   i) Coat the bottom of the shim thinly with gasket sealant LG-6, then assemble the shim.
   ii) Next, coat with gasket sealant LG-6 in the same way as when not using a shim.



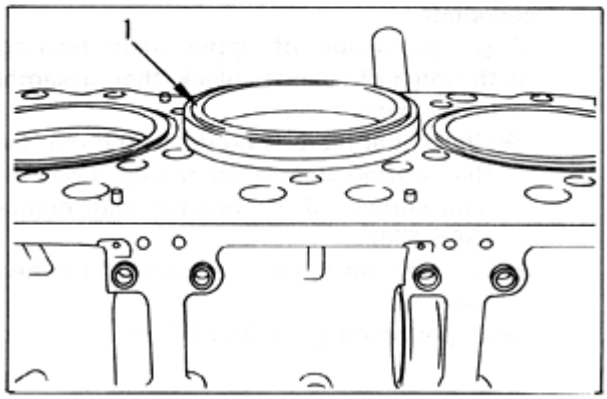
6) Coat the liner O-ring, clevis seal, and cylinder block contact surface with a small amount of engine oil (SAE #30) immediately before press fitting the liner.

★ Coat the contact surface of the cylinder block uniformly around the whole circumference by hand



7) Insert liner (1) into cylinder block, taking care not to damage O-ring.
8) Use your weight and push the liner in with both hands.

★ If the liner does not go in smoothly when you apply your weight, there is danger that the O-ring may be damaged, so check the cylinder block for burrs of flashes.

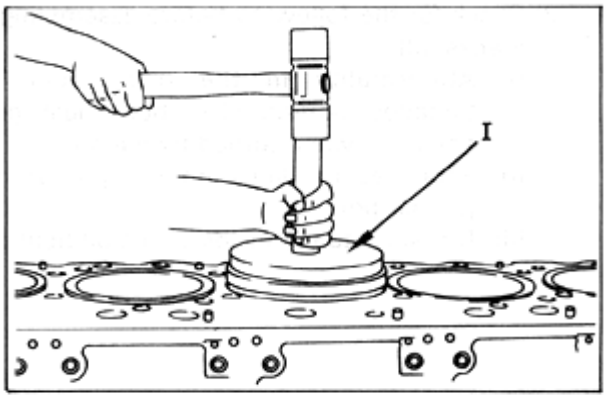


9) Using a liner driver **I**, press fit cylinder liner (1) into the cylinder block.

★ Using the following procedure, squeeze out the gasket sealant coated on the counterbore

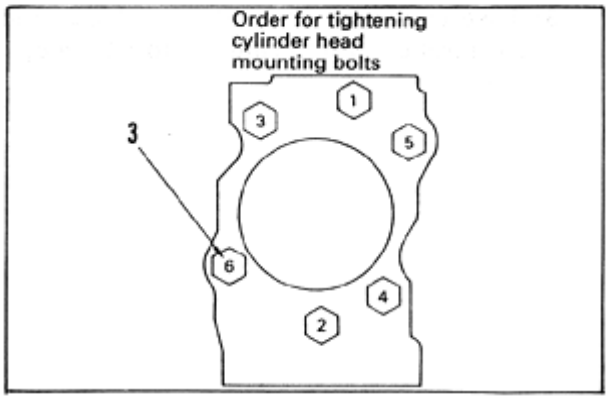
i) Tighten the cylinder head temporarily with a used head gasket.

kgm Mounting bolt: 26 ± 1 kgm



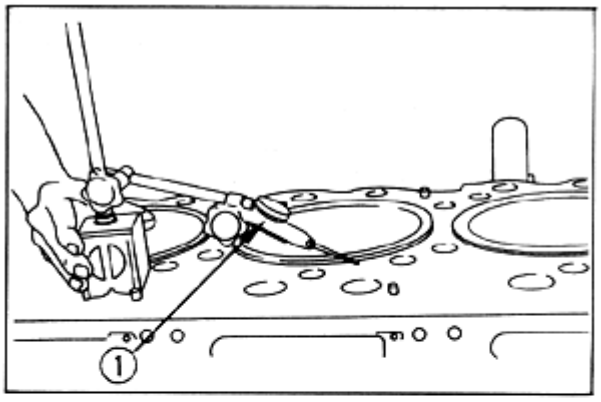
ii) Remove the cylinder head, and wipe off the gasket sealant that has been squeezed out from between the cylinder liner and cylinder block.

★ If gasket sealant sticks to the grommet in the head gasket, the grommet will change shape and cause leakage of water, so be sure to wipe off all the gasket sealant.



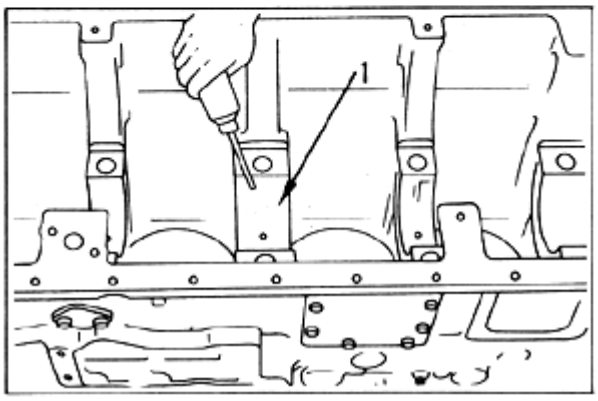
10) After press fitting cylinder liner, use dial gauge ① to measure protrusion of cylinder liner.
   - ★ When measuring the protrusion of the liner, hold the liner down with a plate to prevent the liner from coming up on the O-ring when measuring.
   - ★ Protrusion of cylinder liner : 0.07-0.15mm

★ If it is not within the standard value, take the action given in the maintenance standard.



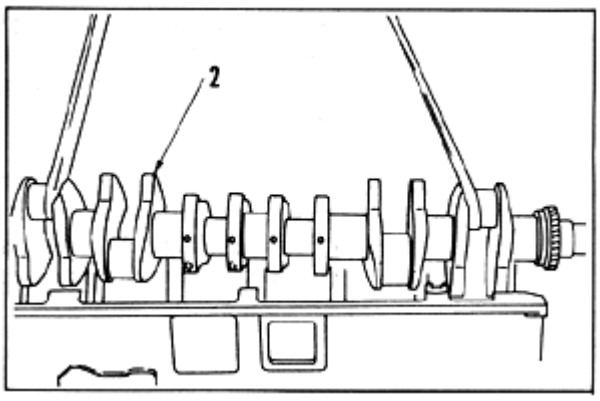
2. Crankshaft

1) Align protrusion of upper main bearing (1) with notch of cylinder block, then assemble in cylinder block.
   - ★ Check that there is no dirt at the rear face of the bearing before tightening. Coat the inside surface of the bearing with engine oil (SAE #30).
   - ★ Do not coat the rear surface of the bearing bearing with oil.
   - ★ Upper bearing: With oil hole

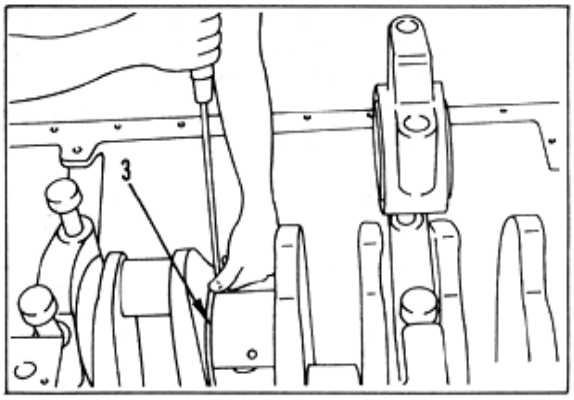


2) Check for the following before assembling the crankshaft.
   - i) Abnormality int the front, rear side threaded portion (The bolt must go in smoothly when turned by hand).
   - ii) Scratches or dents on the pin or main journal portion.
   - iii) Dirt stuck to the inside of the oil hole.

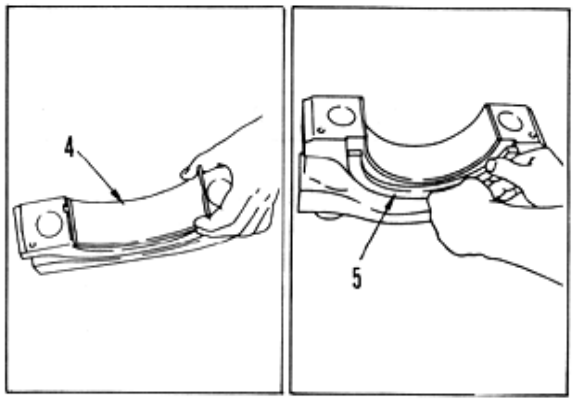
3) Raise crankshaft (2), and assemble to mounting position, taking care not to hit the cylinder block.



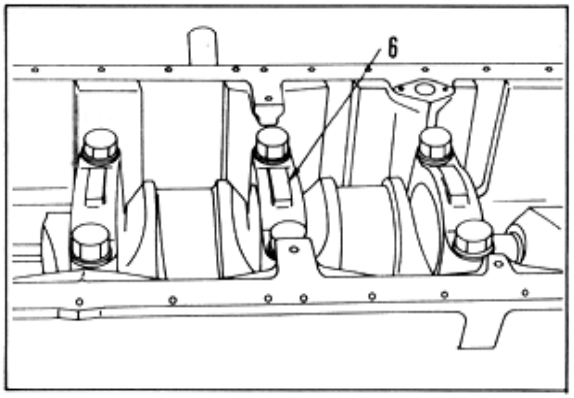
4) Move crankshaft to one side. then coat upper thrust bearing (3) with engine oil (SAE #30), and install to No.6 bearing so that side with oil griive is faing crankshaft end.



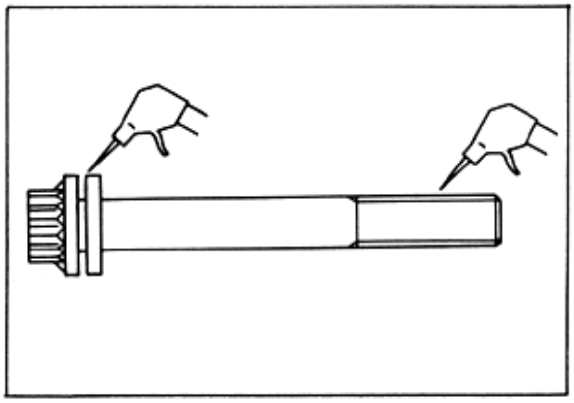
5) Align Protrusion of lower bearing (4) with notch of main cap and install.
   - ★ Check that there is no dirt at the rear face of the bearing before tightening. Coat the inside surface of the bearing with engine oil (SAE #30).
   - ★ Do not coat the rear surface of the beari-bearing with oil.
   - ★ Lower bearing: No oil hole



6) For No. 6 main cap, knock in dowel pin so that protrusion from end face of cap is 3.0 - 3.5 mm, then install lower thrust bearing (5) on both sides.
   - ★ Install the thrust bearing with the side with the groove on the crankshaft side.

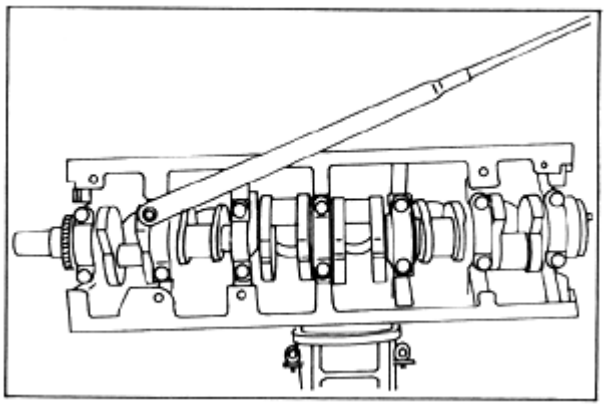


7) Coat journal surface of crankshaft with, engine oil (SAE #30), check that stamped number on main cap (6) matches number on cylinder block, then install main cap.
8) Coat mounting bolt thread and washer of main cap with engine oil (SAE #30), then screw in bolts, and insert main cap completely.



9) Tighten main cap mounting bolts as follows.
   ★ When tightening, start from the center and work in order to the outside. Tighten the bolts to the specified tightening torque using the following steps.

kgm Main cap mounting bolt

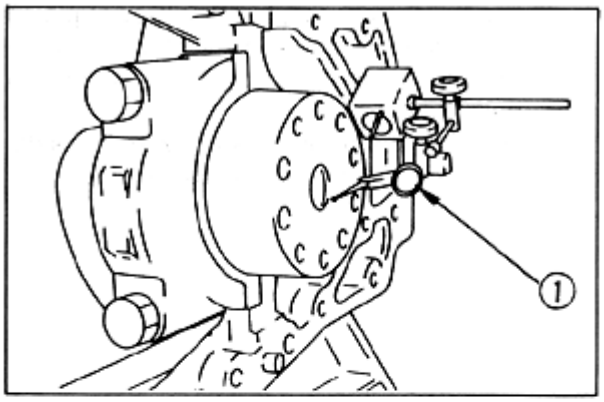


Unit: kgm

Step	Target	Range
1st	56	51 to 61
2nd	113	107 to 118
3rd	0	Loosen completely
4th	38	33 to 43
5th	75	70 to 80
6th	113	107 to 118

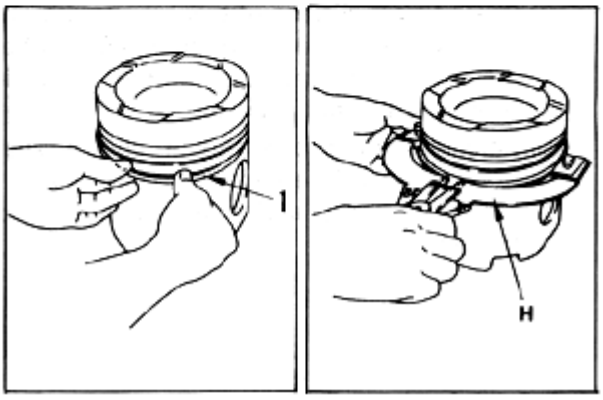
10) After tightening main cap bolts. screw bolt into center bolt hole and measure starting torque of crankshaft.
   ● Standard value: Max. 2.8 kgm

11) Measure end play of crankshaft with dial gauge ①.
   ● End play : 0.140 - 0.32 mm
   ★ If it is within the standard value, take the action given in the maintenance standard.

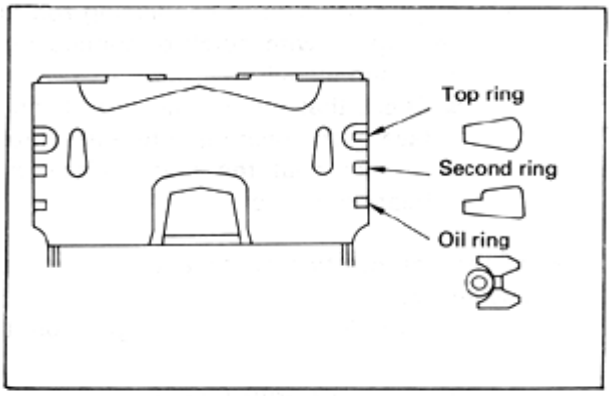


3. Piston, connecting rod assembly
- Assemble piston and connecting rod.
  i) Fit oil ring expander (1) in oil ring groove.
  ii) Using piston ring tool **H**, assemble oil ring, second ring, and top ring in order.

★ Set each ring with the stamped mark facing up and install to the piston.
★ Place the end of the expander coil at 180°to the end gap of the oil ring.



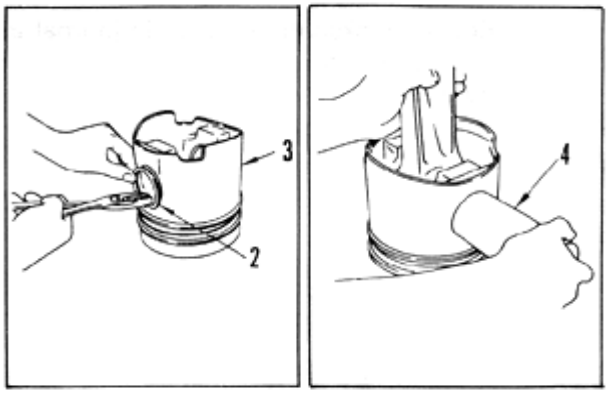
★ Assemble each piston ring as shown in the diagram.



iii) Install snap ring (2) on the side,
iv) Heat piston (3) at 100°C [212°F] for 5 minutes in a heating furnace.

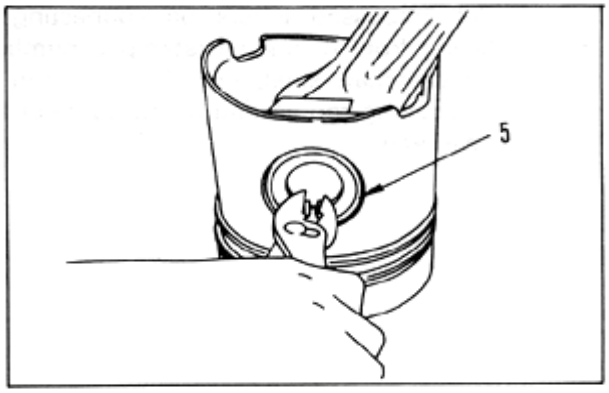
★ If no heating furnace is available, heat in hot water at 100°C [212°F] for 5 minutes.

★ When heating with hot water, clean the piston completely after setting it in position.



v) Coat piston boss with engine oil (SEA #30), set front embossed casting letters on piston facing in same direction as part number casting letters on connecting rod, then insert piston pin (4).
vi) Install snap ring (5) on opposite side.

★ Rotate the left and right snaprings to check that the snap rings ar completely fitted into the ring groove.

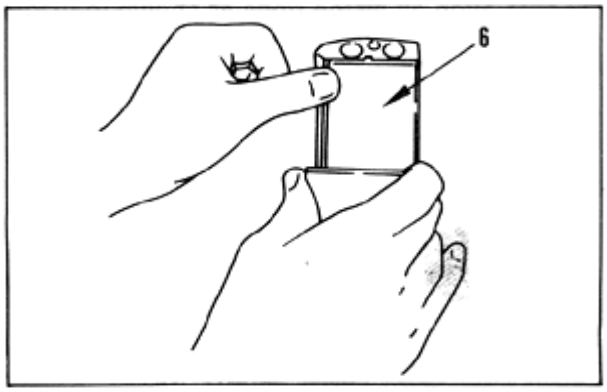


vii) Align protrusion of connecting rod upper bearing (6) with notch of connecting rod, then install.

★ Check that there is no dirt the rear face of the bearing before assembling.

★ Do not coat the rear surface of the bearing with oil.

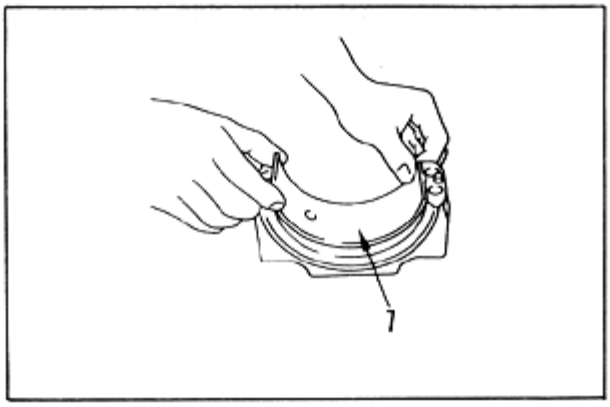
★ Check that the hole in the bearing and the oil hole in the connecting rod are aligned.



viii) Align protrusion of connecting rod lower bearing (7) with notch of connecting rod cap,then install.

★ Check that there is no dirt at the rear face of the bearing before assembling.

★ Do not coat the rear surface of the bearing with oil



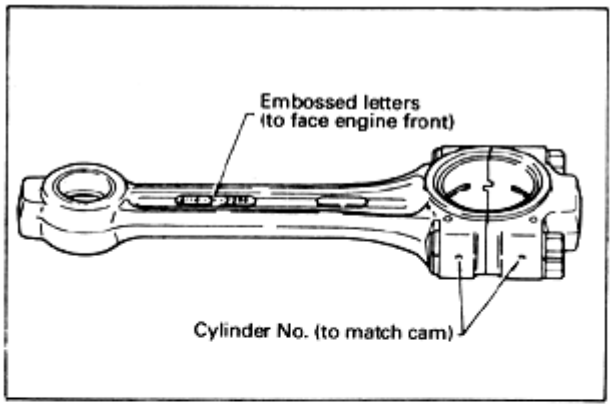
- Method of inserting piston and connceting rod assembly.

1) Coat cylinder liner with engine oil (SAE #30).

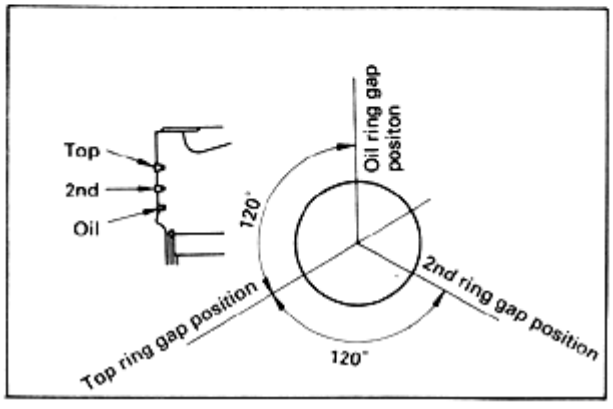
★ Coat uniformly with engine oil around the whole circumference by hand.

2) Rotate crankshaft and set pin journal at top dead center for cylinder where piston is to be inserted.

3) Set embossed letters on conncted rod facing front of engine (stamped number is on camshaft side), then insert piston and connecting rod assembly into cylinder from head end.

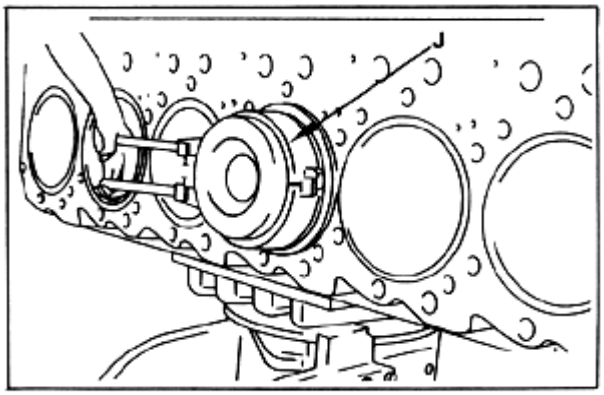


4) Align all piston rings as shown in diagram.



5) Coat piston ring uniformly with engine oil (SAE #30).

6) Tighten piston ring with piston ring holder **J,** then push in piston head with wooden bar.

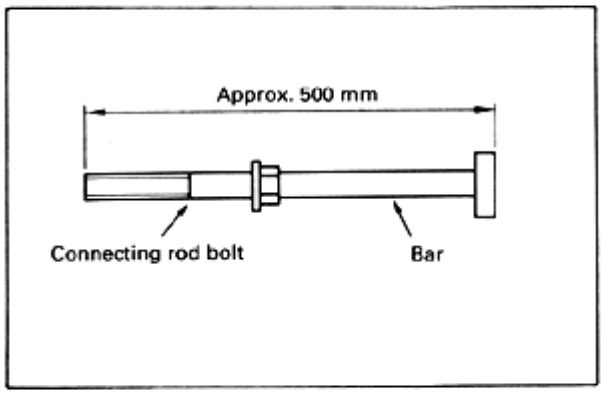


7) Using connecting rod pulling tool shown in the diagram on the right, pull connecting rod, and fit it in close contact with crank pin journal.

★ Check that the connecting rod bearing is correctly in position.

★ To make a connecting rod pulling tool, weld a bar to an old connecting rod bolt.

8) Coat crankshaft pin journal with engine oil (SAE #30).

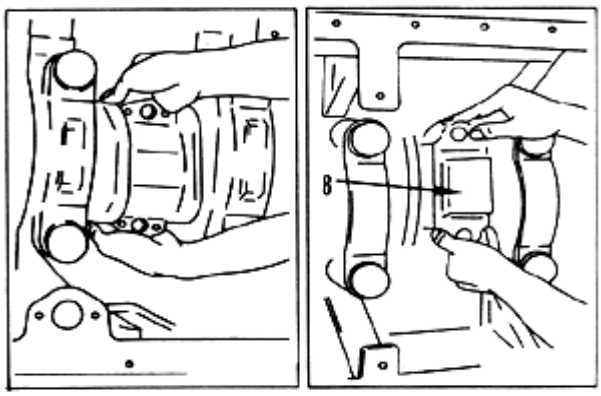


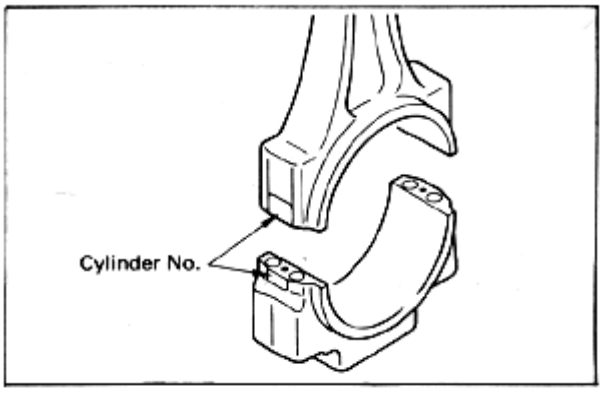
9) Rotate crankshaft 180° while pulling conecting rod.

10) Coat connecting rod lower bearing with engine oil (SAE #30), check cap number, then align with dowel pin, and install connecting rod cap (8).

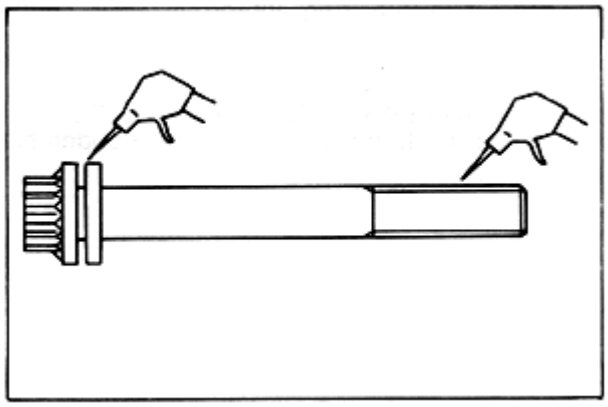
★ When coating with engine oil, spread the oil with a finger over the whole part.

★ When assembling a new connecting rod, mark the cylinder number with an electric pen. Do not make a stamped mark.





11) Coat thread and washer of connecting rod bolt with engine oil (SAE #30).



12) Tighten connecting rod bolts in turn until connecting rod cap is in tight contact.
   ★ If an impact wrench is used to loosen the bolts, there is danger of damage to the thread, so loosen the bolts with a hand tool.

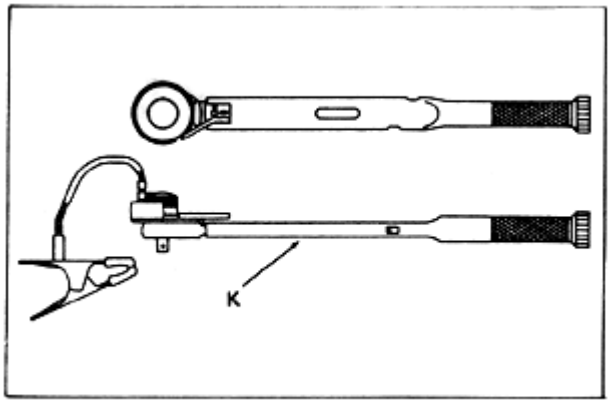
13) Rotate crankshaft 180° and repeat Steps (1 to 12) to insert pistons in all cylinders.

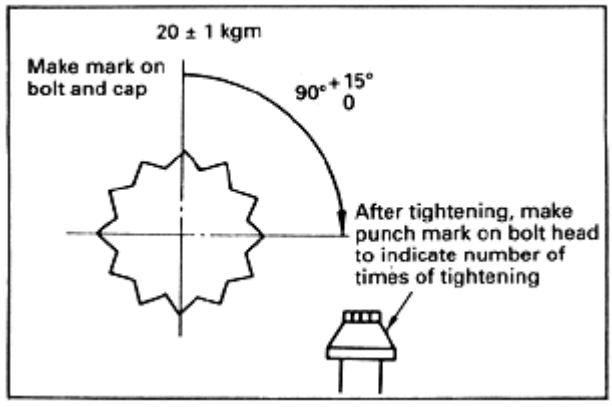
14) Tighten the connecting rod bolts as follows.
   i) 1st step : Tighten 20 ± 1 kgm
   ii) 2nd step : Using wrench **K** turn 90° $^{+15°}_{0}$ to tighten.

- When not using wrench **K** tighten as follows.
   i) 1st step : Tighten 20 ± 1 kgm
   ii) 2nd step : Put a mark on the bolt and cap with a felt pen, then turn the bolt a further 90° $^{+15°}_{0}$

★ After tightening, make one punch mark on the bolt head. If the bolt head has five punch marks, do not reuse it. Replace the bolt with a new bolt.

★ After assembling the connecting rod, check that the crankshaft rotates smoothly.

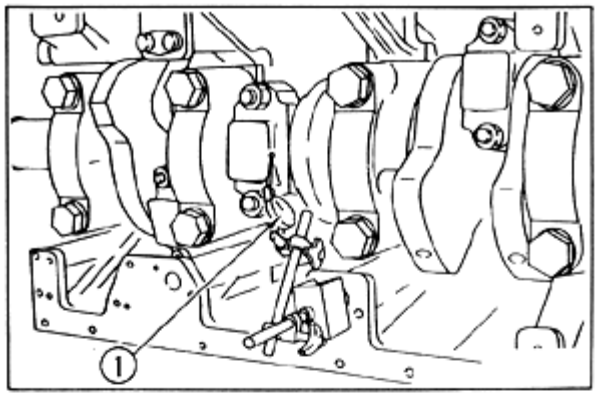




15)Using dial gauge①. measure side clearance of connecting rod.

★ Standard for side clearance : 0.200 - 0.375 mm

★ If the connected rod does not move, remove the connectingrod cap and check that there is no mistake in assembly, and that there are no burrs, or dirt caught anywhere.



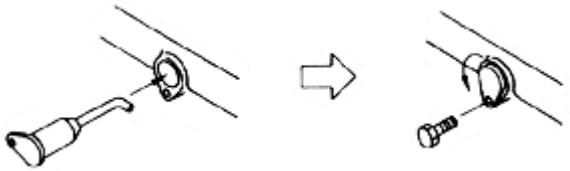
4. Piston cooling nozzle

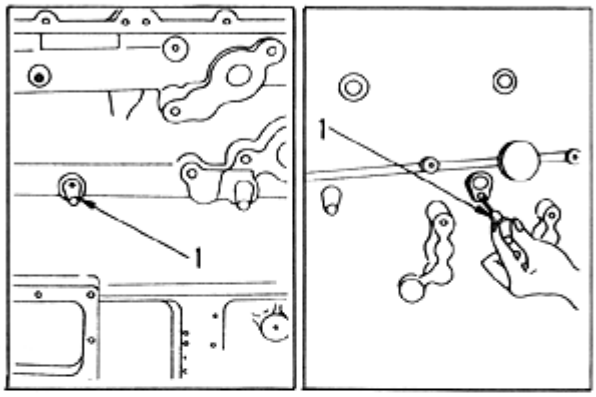
Fit O-ring to cooling nozzle (1) and install.

O-ring : Engine oil (SAE #30)

★ Before installing,check the curvature (angle) of the nozzle, and check that there is no clogging inside the nozzle.

★ Face the tip of the nozzle to the side with the mounting hole at the side, insert into the piston, taking care that it does not hit the piston, then turn 90°





5. Flywheel housing

1) Fit gasket to mounting surface of cylinder block, then using eyebolts (Thread dia. = 16 mm, Pitch = 2.0 mm), raise flywheel housing (1) and install to cylinder block.

Mounting bolt :
1st step : Tighten to 36 - 40 kgm
kgm 2nd step : Loosen completely
3rd step : Tighten to 40 - 44 kgm

★ Tighten the mounting bolts of the flywheel housing as follows, in the order shown in the diagram.

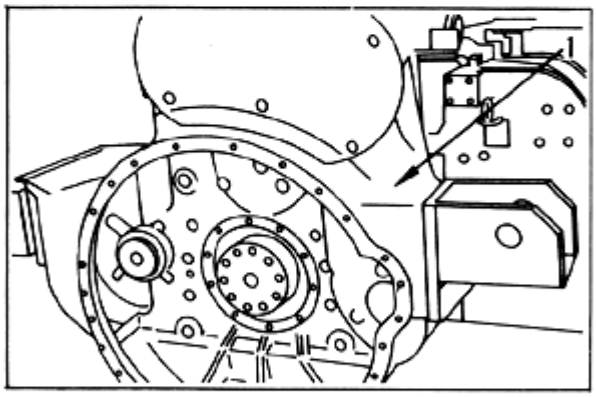
★ The bolts are of different legths, so be careful when installing them.

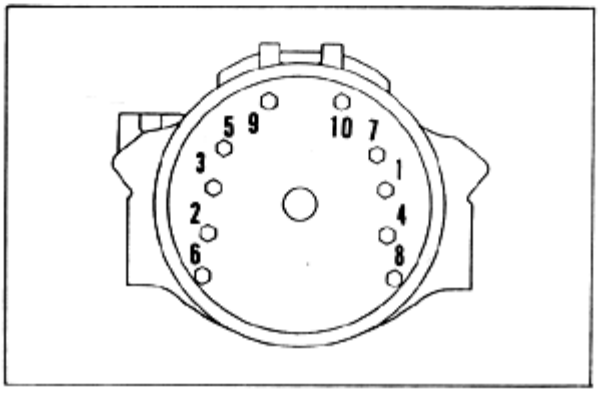
2) After installing flywheel housing, using dial gauge to measure face runout and radial runout.

★ • Face runout : Max. 0.20 mm
• Radial runout : Max. 0.20 mm

3) Inspect stepped difference between cylinder block and flywheel housing.

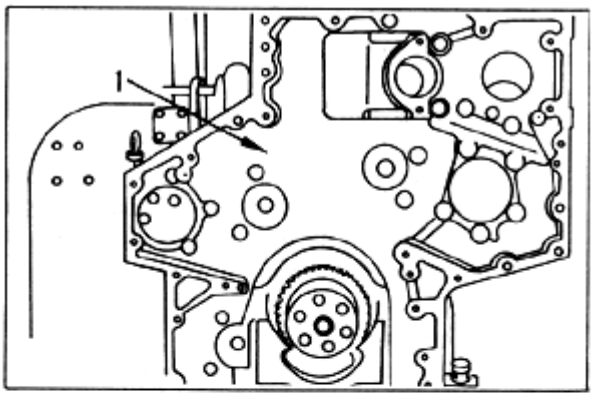
★ Stepped difference at bottom surface :
Max. 0.15





6. Gear case

1) Fit gasket to mounting surface of gear case.
2) Install gear case (1).



7. Main idler gear

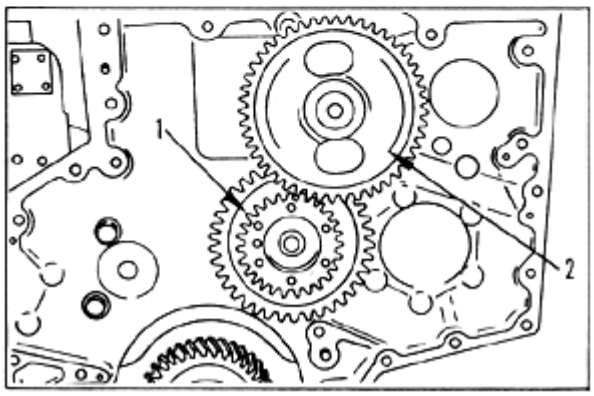
Install main idler gear (1).

★ Assemble with the oil groove of the thrust bearing on the gear side.
● Press fit the thrust plate to the shaft.

Coat the bolt thread and seat with engine oil (SAE #30), then tighten.

★ When installing the mounting bolts, screw in first at least 2-3 turns by hand, then tighten as follows. (All models)

kgm Idler gear mounting bolt:



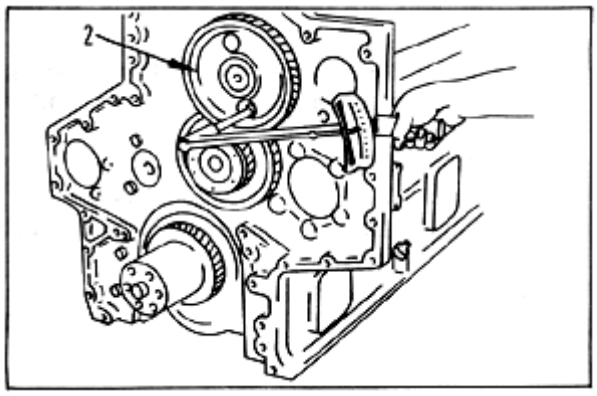
(Thread size) x (Pitch)	Tightening method
M16 x 1.5	30 - 35 kgm (Tighten by torque)
M18 x 2.5	5 ± 0.5 kgm 90 $^{+30°}_{0}$ Tighten an additional
M18 x 1.5	31 ± 4 kgm 90 $^{+30°}_{0}$ Tighten an additional

★ After tightening, make one punch mark on the bolt head to indicate the number of times that the bolt has been used. If any bolt has four punch marks, do not reuse it. Replace it with a new bolt.
★ Align carefully with the match marks on the gear when installing.

8. Camshaft

Coat surface of camshaft journal with engine oil (SAE #30) and install camshaft (2).

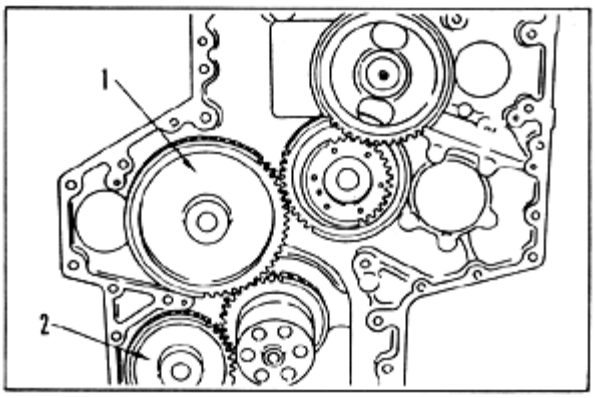
kgm Camshaft plate : 3.1 - 43 kgm



★ When inserting the cam shaft, rotate it while inserting it in order to prevent damage to the cam bushing.
★ Align carefully with the match marks on the gear when installing.

9. Idler gear for oil pump

Install idler gear (2) for oil pump.



kgm Idler gear mounting bolt:

(Thread size) x (Pitch)	Tightening method
M16 x 1.5	30 - 35 kgm (Tighten by torque)
M18 x 2.5	5 ± 0.5 kgm 90 $^{+30°}_{0}$ Tighten an additional
M18 x 1.5	31 ± 4 kgm 90 $^{+30°}_{0}$ Tighten an additional

- Be sure to install the thrust bearing with the oil groove facing in the correct direction.
- Coat the bolt thread and seat with oil.
- When installing the mounting bolts, screw in first at least 2 - 3 turns by hand, then tighten fully.
- After tightening, make one punch mark on the bolt head to indicate the number of times that the bolt has been used.

★ Align carefully with the match marks on the gear when installing.

10. Idler gear for water pump

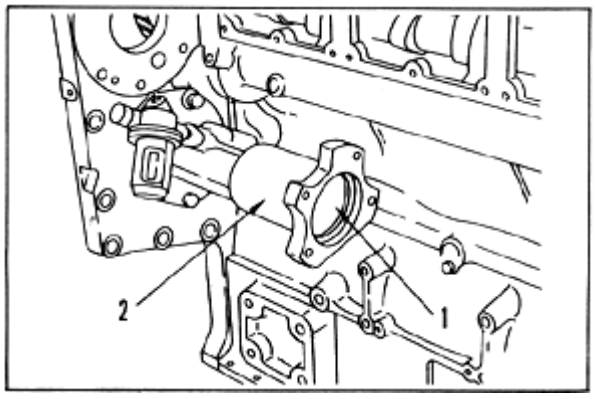
Install idler gear (1) for water pump.

★ Align carefully with the match marks on the gear when installing

kgm Idler gear mounting bolt for water pump : Same as in item 9 above

11. Injection pump drive case

1) Fit O-ring and install injection pump drive case (2).
2) Install coupling (1).

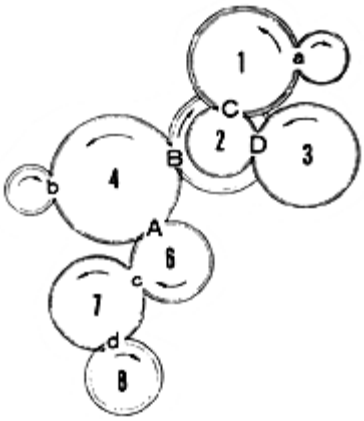


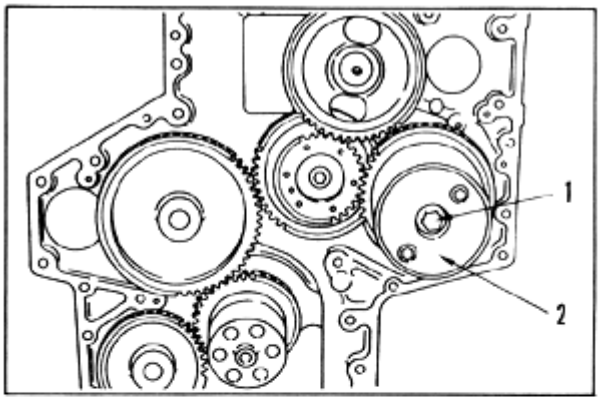
12. Timer

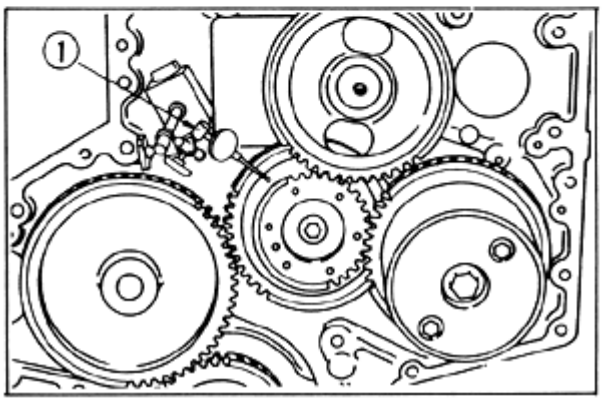
Install timer (2) aligning it with the gear, then tighten nut (1).

kgm Timer nut : 1.75 ± 2.5 kgm

- ★ Align the match marks on the timer and the gear surely.
- ★ Measure the backlash and end play of each gear with dial gauge①.
- ★ Standard value of backlash and end play :







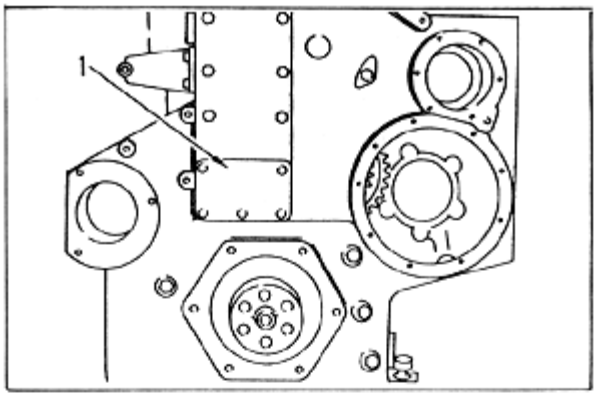
Without a timer

Backlash		End play	
A	0.140 - 0.460	1	0.075 - 0.21
B	0.130 - 0.470	2	0.10 - 0.32
C	0.130 - 0.470	3	* 0.145 - 0.395
D	0.100 - 0.500	4	0.10 - 0.32
a		5	
b	0.095 - 0.460	6	0.14 - 0.32
c	0.120 - 0.425	7	0.10 - 0.32
d	0.100 - 0.445	8	0.085 - 0.125

* End play (3) for machines with a timer (HD465 twin turbo, WA700 only) is 0.09 - 0.45 mm. For other machines the backlash and end play are as in the talble above.

13. Gear case cover

1) Stick gasket to mounting surface for gear case cover.
2) Install gear case cover (1).
   - ★ Check the difference in level between the gear case, gear cover, and the bottom face of the cylinder block.
   - ★ Difference in level of bottom face : Max. 0.15 mm

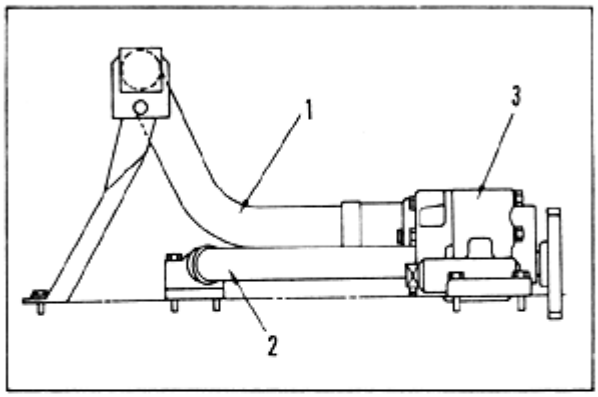


14. Oil pump assembly

1) Install oil pump assembly (3).

kgm Mounting bolt : 11.0 ± 1.5 kgm

2) Fit gasket, O-ring and install tube (2).



15. Oil strainer

Fit gasket, then install oil strainer (1) and secure with bracket.

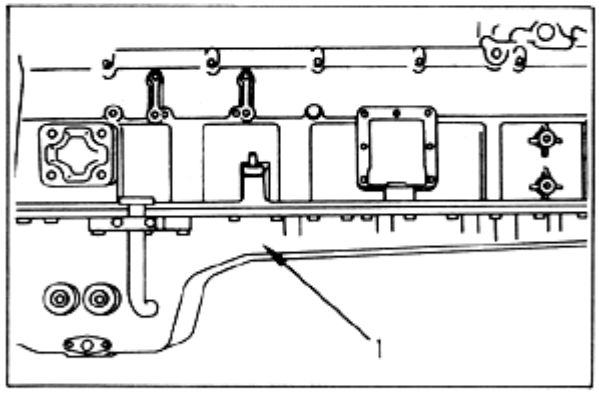
16. Oil pan

- ★ Before installing the oil pan, cut off the gaskets of the flywheel housing, gear case, and gear cover so that they are the same level as the cylinder block.

Apply liquid gasket to the face of the oil pan, and install oil pan (1).

Face of oil pan : Liquid gasket (LG-7)

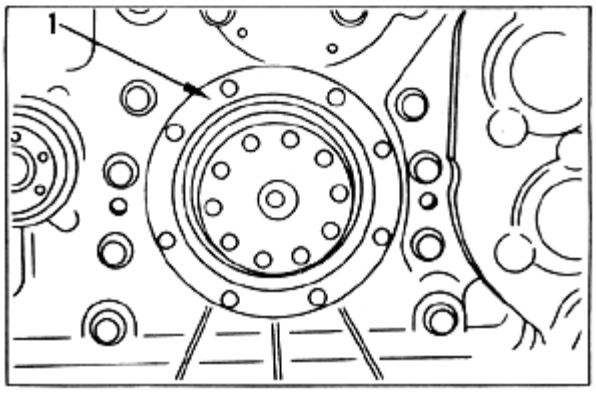
- ★ Diameter of gasket sealant: ϕ 1.6 - 2.0mm



17. Rear seal cover

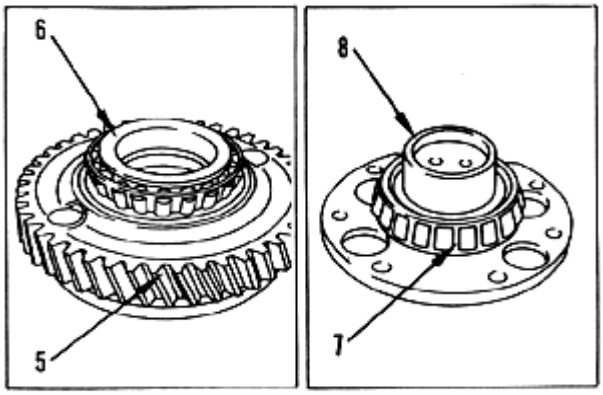
Fit O-ring and install rear seal cover (1).

- ★ Take care that the lip is not rolled up

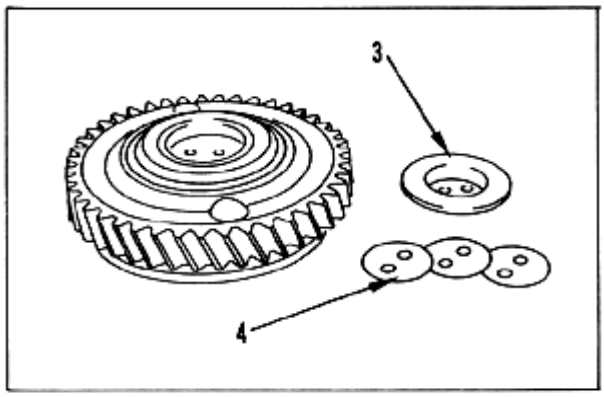


18. PTO drive gear

★ Assemble PTO drive gear as follows:
  i) Install bearing (7) to shaft (8).
  ii) Install the snap ring to gear (5), then install bearing (6).
★ Coat the bearing portion with engine oil (SAE #30).

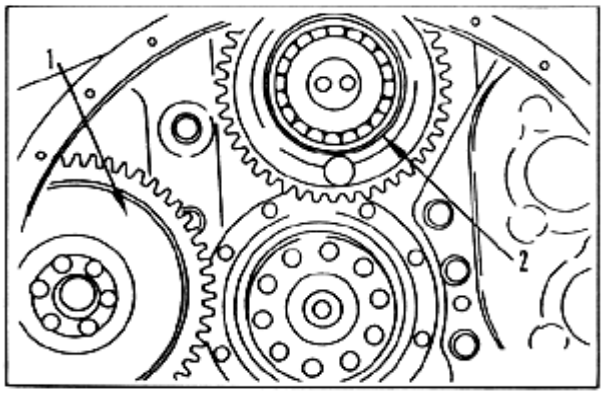


  iii) Install shim (4),then install retainer (3).
    ★ Bend the lock plate securely.
    ★ Confirm that the gear can rotate smoothly. If not, adjust the thickness of the shim.



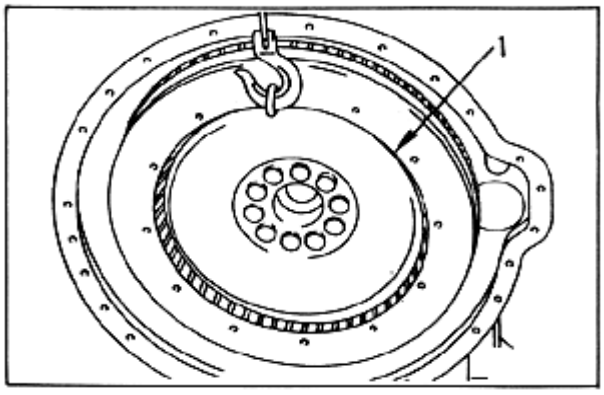
1) Install PTO drive gear (2), and then tighten six bolts.
  ★ After installing PTO drive gear, confirm that there is backlash between it and the PTO gear,
  ★ Backlash: 0.15 to 0.52 mm

2) Install steering pump drive gear (1).
  ★ Bend the lock plate securely.

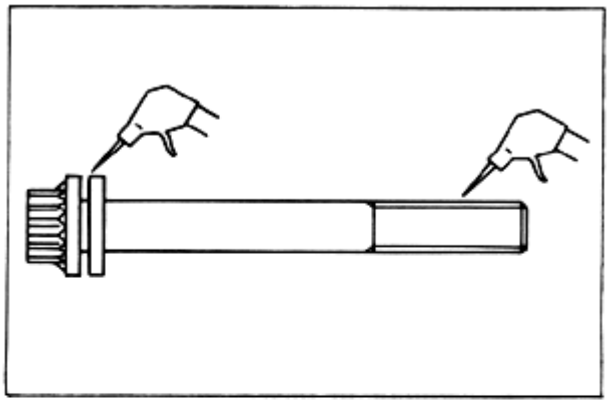


19. Flywheel

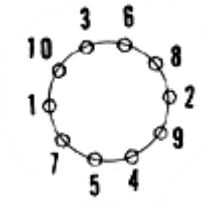
1) Using eyebolts (Thread dia.= 12 mm, Pitch= 1.75 mm), raise flywheel (1), mesh train gear and idler gear, then install flywheel and tighten bolts.
  ★ For engine with a PTO:
  When measuring the engine capacity, the inside of the PTO case cannot be lubricated, so remove the PTO drive gear and install the flywheel.

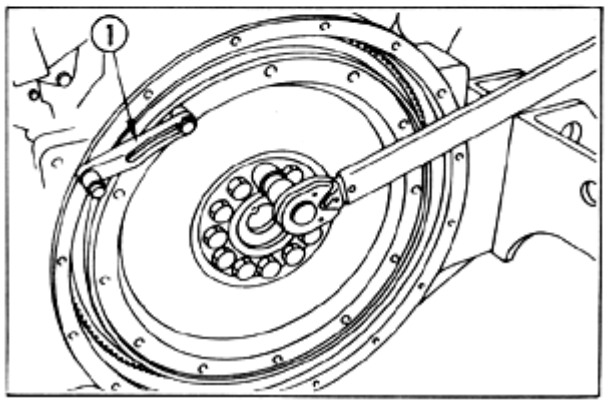


2) Coat bolt thread and washer with engine oil (SAE #30) or anti-friction compound (LM-P).
3) Tighten bolts in turn unit flywheel is in tight contact.
   ★ If impact wrench is used to loosen the bolts, there is danger of damage to the thread, so loosen the bolts with a hand tool.



4) Secure flywheel and housing with stopper ① and tighten bolts.
   ★ Order of tightening





kgm Flywheel mounting bolt (BHD465)

1st step :	Tighten to 20 ± 2 kgm
2nd step :	Tighten to 47 ± 2 kgm
3rd step :	Make marks on bolts and flywheel with felt pen, then tighten bolt an additional 90 $^{+30^\circ}_{0}$

kgm Flywheel mounting bolt (machines except HD465):

1st step : 8 - 12 kg
2nd step : 28 - 32 kgm
3rd step : 53 - 57 kgm

5) Measure radial runout and face runout of flywheel .
   ★ Radial runout and face runout of flywheel

Item	Except BHD465	BHD465 only
Radial runout (pilot bearing hole)	Max. 0.15 mm	0.10 mm
Face runout	Max. 0.20 mm	0.20 mm

20. Cam follower

1) Install cam follower assembly (2), aligning it with the pin

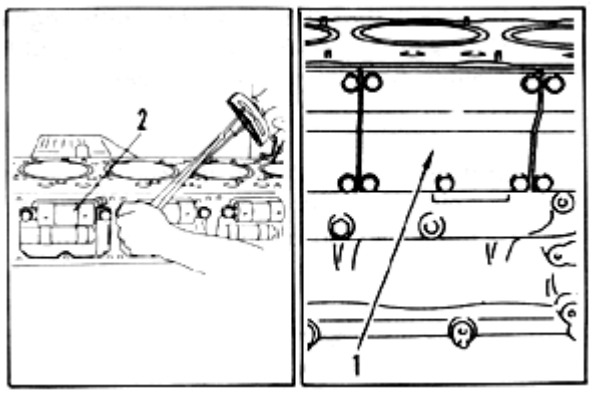
kgm Cam follower mounting bolt : 9.2 - 10.6 kgm

★ Before installing the cam follower, wash the oil hole of the mounting bolt.

2) Install cover (1).

Face of cover : Liquid gasket (LG-7)

★ Diameter of gasket sealant: Ø1.6 - 2.0



21. Mechanical pump assembly

Fit O-ring to mechanical pump assembly (6), then align with slit at tip of camshaft, and intall.

22. Accessory drive pulley

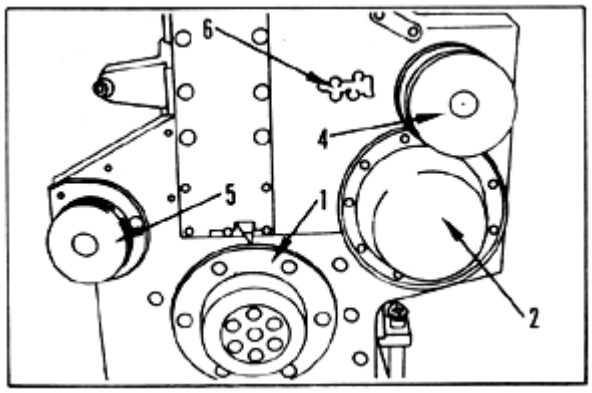
1) Fit O-ring and install drive pulley (5) for alternator.
2) Fit O-ring and install accessory drive pulley (4).

23. Trunnion

1) When press fitting front seal, use a tool.
   ★ After press fitting, check that the spring has not come cut of position.

Lip of oil seal : Grease (G2-LI)

2) Fit O-ring and install trunnion (1).
   ★ Before installing the trunnion, clean off all dirt from the outside circumference of the crankshaft, then coat the whole circumference thinly with engine oil (SAE #30).
   ★ Take care that the lip is not rolled up.



24. Cover

Install cover (2).

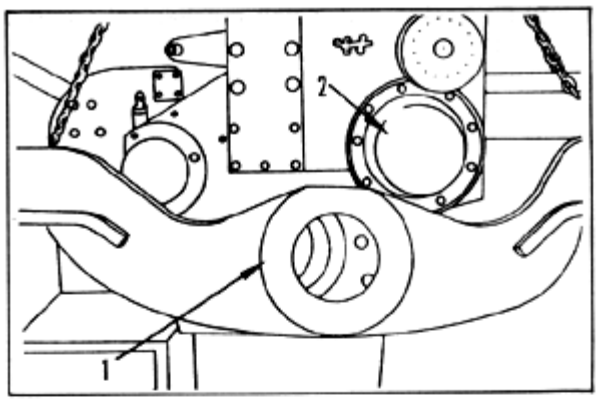
Face of cover : Liquid gasket (LG_-7)

★ Diameter of gasket sealant : Ø1.6 -2.0 mm

25. Front support

Raise front support (1) and install to trunnion portion.

Front support grease groove : Grease (G2-LI)



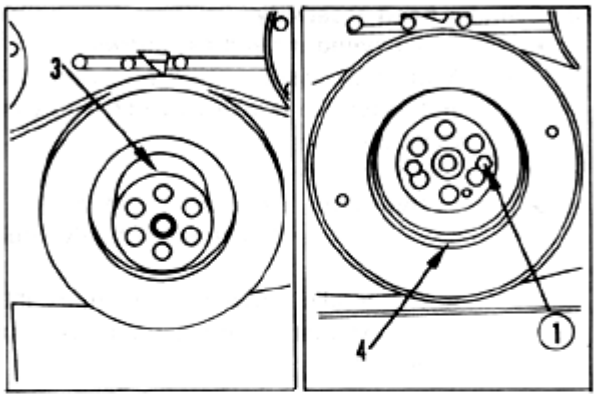
26. Vibration damper

1) Sling vibration damper (4), align with dowel pin, and install,
2) Install spacer (3).

27. Crankshaft pulley

1) Install crankshaft pulley (2) and tighten with mounting bolts

Coat bolt thread and seat surface with engine oil (SAE #30), then tighten bolts.



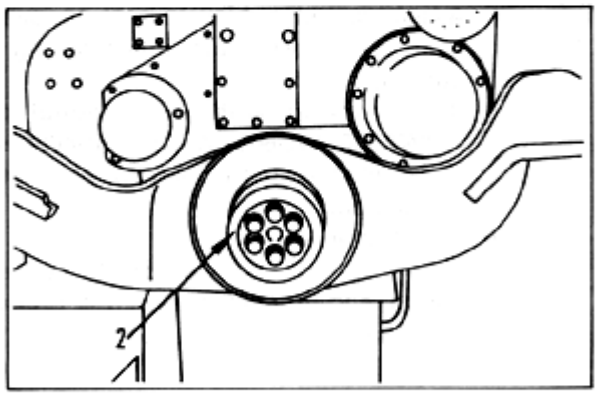
★ When installing the mounting bolts, screw in first at least 2 - 3 turns by hand, then tighten as follows.

kgm

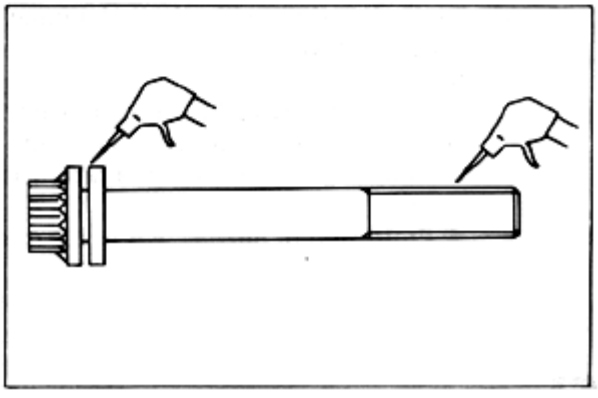
Crankshaft pulley mounting bolt :

Unit: kgm

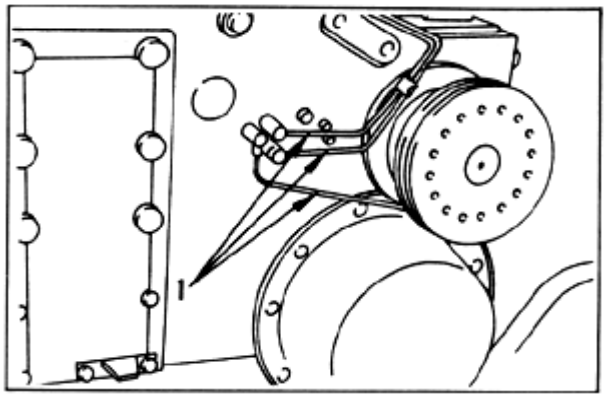
Order	BHD465 only	Except BHD465
1st step	40± 3	7.5 ± 2
2nd step	78±3	25±2
3rd step	Make marks on bolt and pulley with felt pen, then tighten bolt an additional 90 $^{+30°}_{0}$	65±2



★ If an impact wrench is used to loosen the bolts, there is danger of damage to the thread, so loosen the bolts with a hand tool.



2) Fit gasket and install mechanical pump tubes (1).

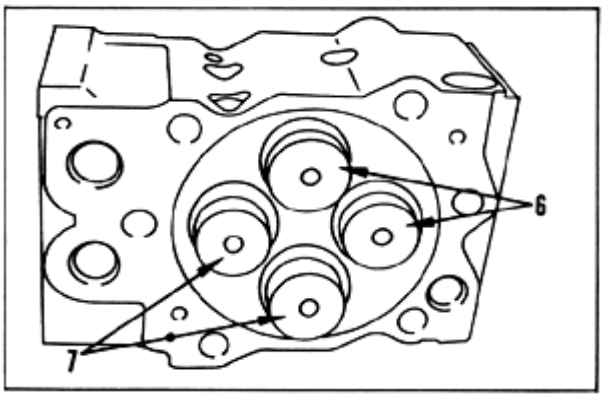


28. Cylinder head assembly

- Assemble cylinder head as follows.
  i) Align with casting mark on cylinder head and assemble intake valve (7) and exhaust valve (6).

Valve stem : Engine oil (SAE #30)
(Inside face of valve guide)

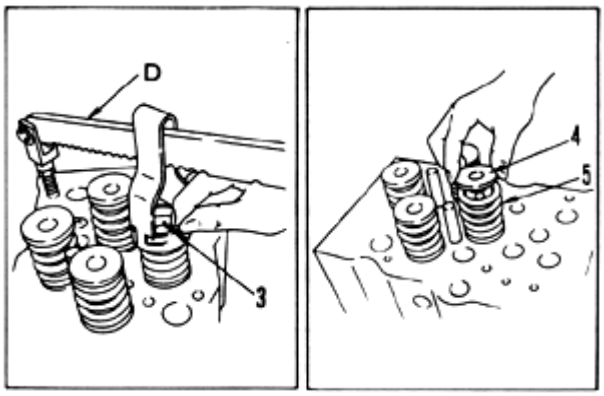
★ The intake valve has the mark **IN** and the exhaust valve has the mark **E** on the bottom.



ii) Assemble valve blower seat to cylinder head, then assemble inner spring and outer spring (5).
★ The spring with the unequal pitch (WA600, WD600, WA700, HD465) is assembled with the narrow pitch at the head end.

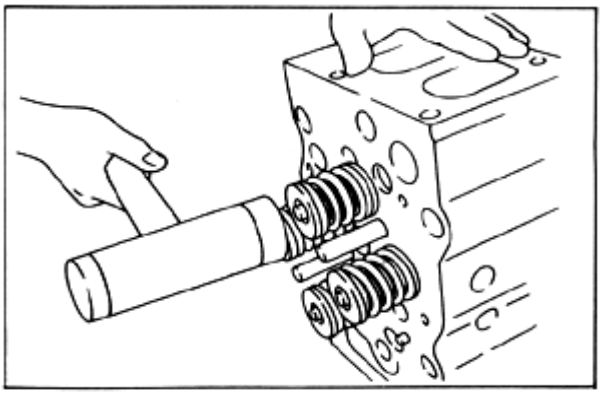
iii) Install retainer (4).

iv) Using spring compressor **D**, compress spring, and fit valve cotter (3) in grrove of valve stem.



v) Tap valve stem with plastic hammer and check that, valve cotter is completely fitted.

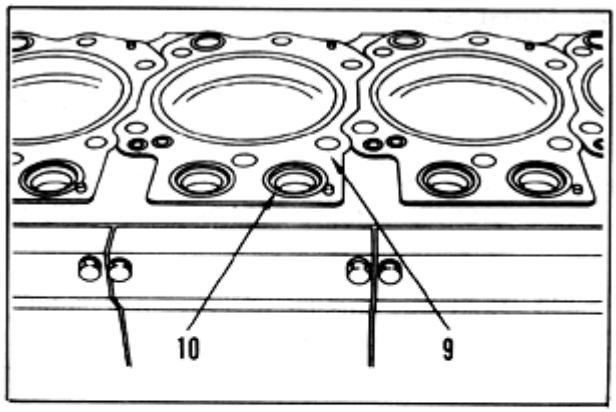
vi) When nozzle valve has been replaced, install nozzle holder to cylinder head, then use depth gauge to measure protrusion of nozzle.
★ Protrusion of nozzle: 4.9 - 5.7 mm



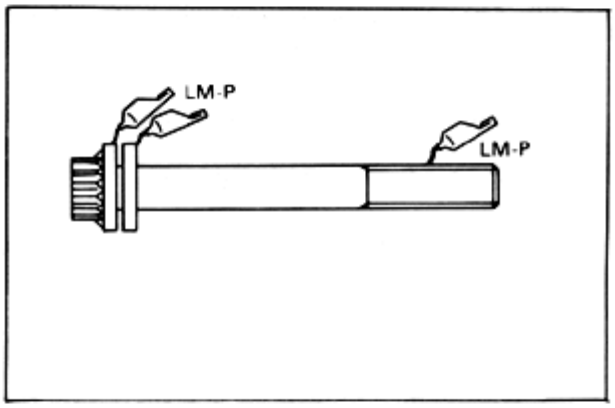
28. Cylinder head assembly

1) Check that there is no dirt on cylinder head mounting surface or inside cylinder, then install gasket (9).
   ★ When installing the gasket, check that grommet (10) has been properly installed and has not peeled off.

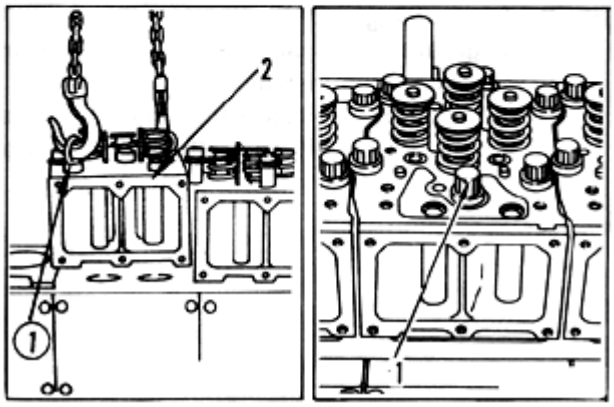
Note: There is danger that the head gasket grommet may swell and change shape, so do not coat it with gasket sealant.

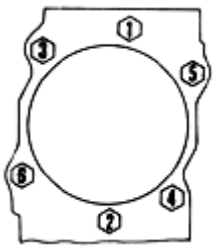


2) Coat thread of head bolt and washer with antifriction compound (LM-P).



3) Using eyebolts 1 (Thread dia. = 12 mm, pitch = 1.75 mm), install cylinder head assembly (2).
4) Screw in head bolts (1) at least 2 - 3 turns by hand, then tighten in order shown in diagram below.





kgm Cylinder head mounting bolt:

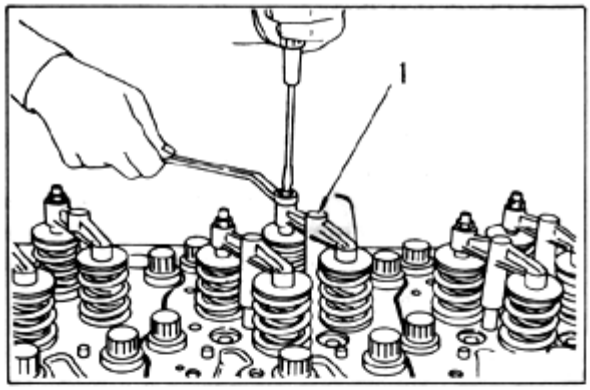
Unit: kgm

Step	Target	Range
1st	7.9	6.4 to 9.4
2nd	23.5	22 to 25
3rd	39	37.5 to 40.5
4th	50.5	49 to 52

29. Crosshead

Install crosshead (1).

Guide pin : Engine oil (SAE #30)



★ Adjust the crosshead as follows.

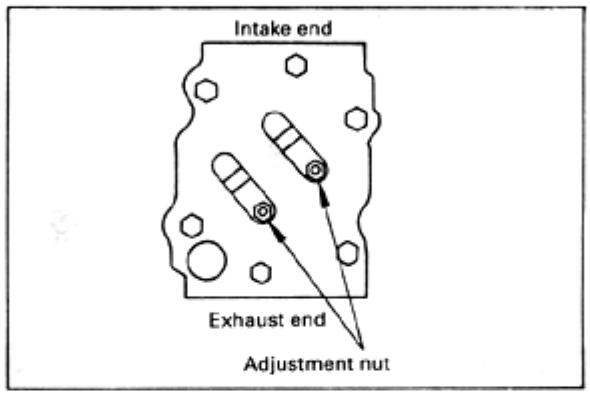
i) Loosen locknu, and turn back adjustment screw.

ii) Hold top surfaces of crosshead lightly, and screw in adjustment screw.

iii) After adjustment screw contacts valve stem, screw in a further 20°.

iv) Tighten locknut to hold in position.

kgm Locknut 4.0 ± 0.6 kgm

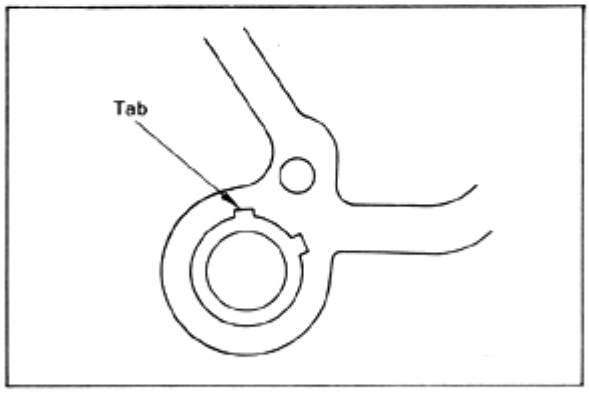


★ Install the crosshead so that the adjustment nut is at the exhaust end.

30. Rocker housing

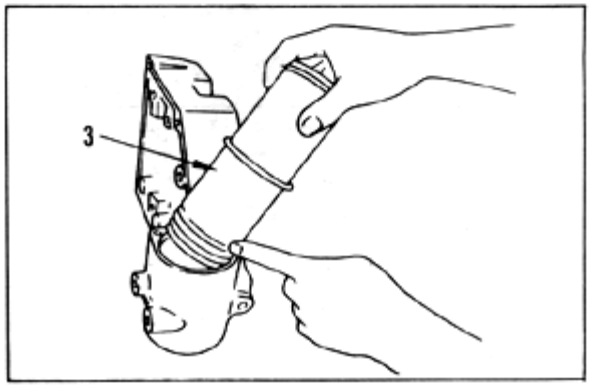
1) Fit gasket, align tab of grommet with groove in gasket, then install.

★ The grommet has a top and bottom, so be sure to install it facing the righ way up.



2) Fit O-ring, then insert water manifold (3) in rocker housing.

O-ring: Engine oil (SAE #30)



★ If the O-ring is coated with engine oil and left for a long time, it will swell, os coat it with oil immediately before assembling it.

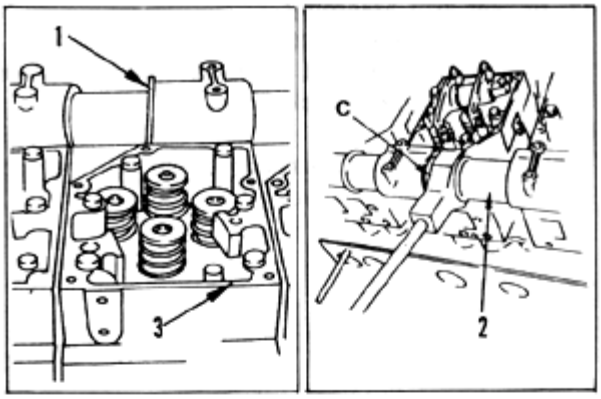
★ Insert the snap ring groove end into the rocker housing.

3) Install rocker housing (3),

kgm Mounting bolt : 10 ± 0.5 kgm

4) Using push tool **C**, insert water manifold (2).

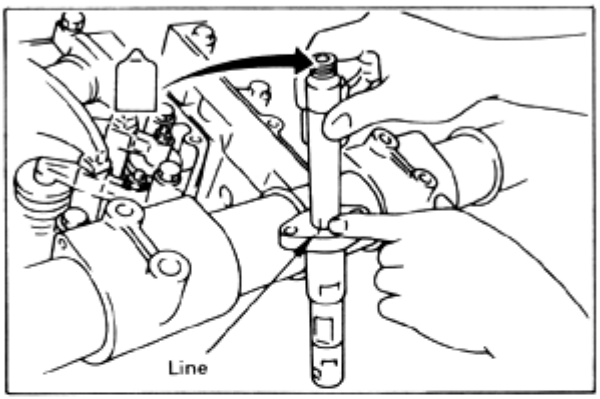
5) Secure water manifold with snap ring (1).



31. Injection nozzle assembly

★ Check that there is no dirt or dust inside the nozzle holder sleeve. (Mark it with a rubber cap.)

1) Align line on nozzle body with line on plate, then set with lines facing front of engine, and install injection nozzle assembly (1).

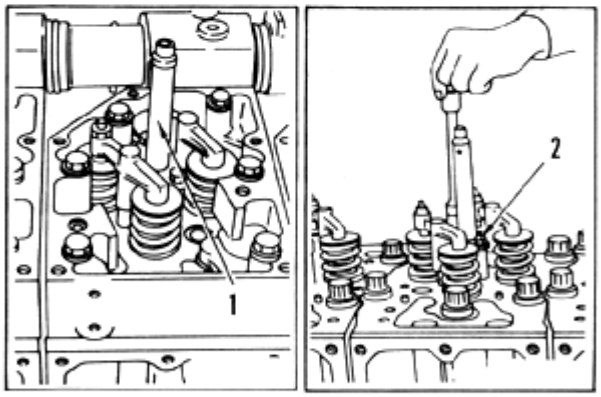


2) When tightening 2 mounting bolts (2), tighten each in turn to a low torque, then gradually increase torque of each bolt in turn (approx. 0.5 kgm each time) to tighten to specified torque.

★ Do not reuse nylock bolts. Always replace them with new parts.

kgm Mounting bolt: 2.75 ± 0.25 kgm

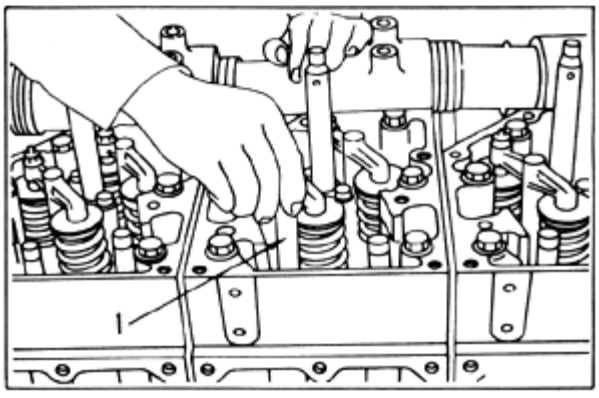
★ Keep the difference in torque between the two bolts to a maximum of 0.5 kgm.



32. Push rod

Install push rod (1).

★ Check that the push rod is fitted properly into the socket of the cam follower.

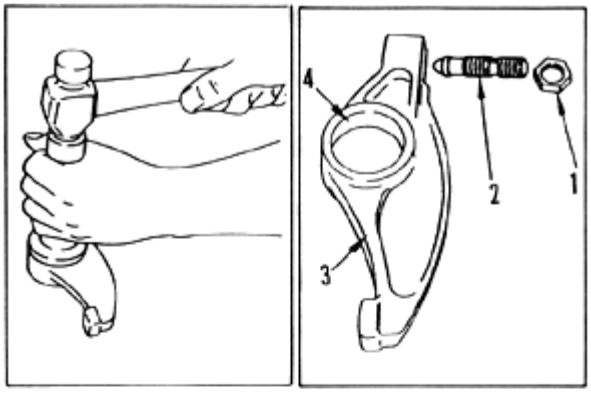


33. Rocker arm assembly

Assemble rocker arm.

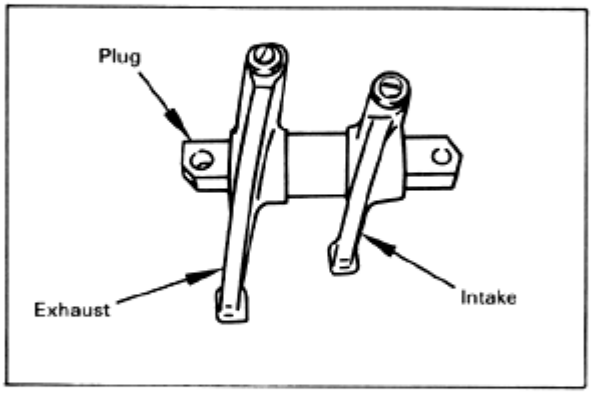
i) Using push tool, align oil hole of bushing (4) and knock in rocker arm (3).

ii) Assemble adjustment screw (2) and locknut (1) to rocker arm.



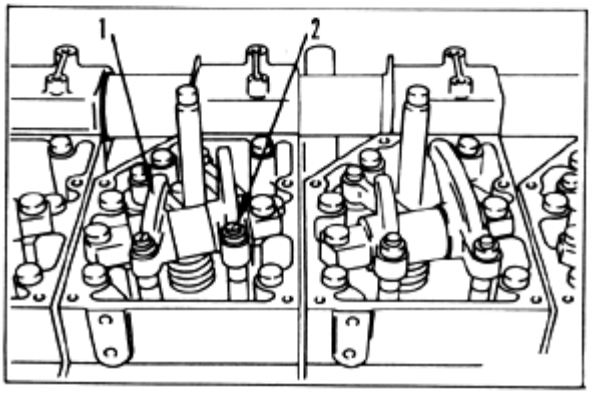
iii) Coat rocker shaft with engine oil (SAE #30), then set so that portion with plug is at exhaust end.

iv) Set exhaust rocker arm (long arm on left and intake rocker arm (short arm) on right, insert collar at center, then insert onto rocker shaft.



1) Install rocker arm assembly (1) and tighten mounting bolts.
   - ★ Check that the ball of adjustment screw (2) is fitted properly into the socket of the push rod
   - ★ Assemble a spacer (length: 15 mm) to the short bolt and a washer to the long bolt.

kgm Mounting bolt: 10 ± 0.5 kgm



34. Adjusting valve clearance

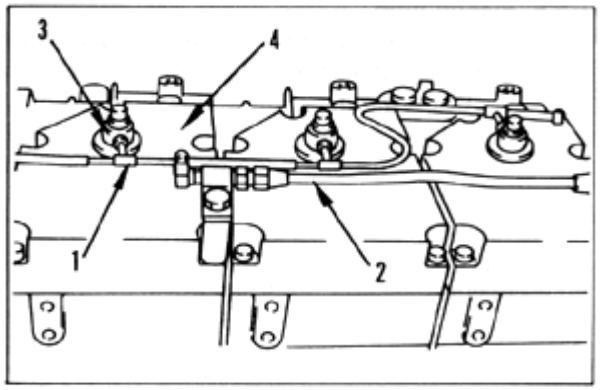
Adjust valve clearance.

For details, see TESTING AND ADJUSTING, Adjusting valve clearance.

35. Head cover, spill tube

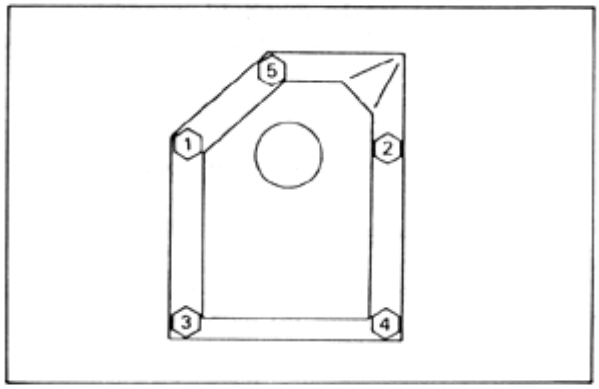
1) Fit gasket, install head cover (4), then tighten bolts temporarily.
2) Install nozzle seal and press fit with push tool.

Nozzle seal surface: Engine oil (SAE #30)



3) Tighten head cover mounting bolts in orders hown in diagram.

kgm Mounting bolt: 3.25 ± 0.25 kgm

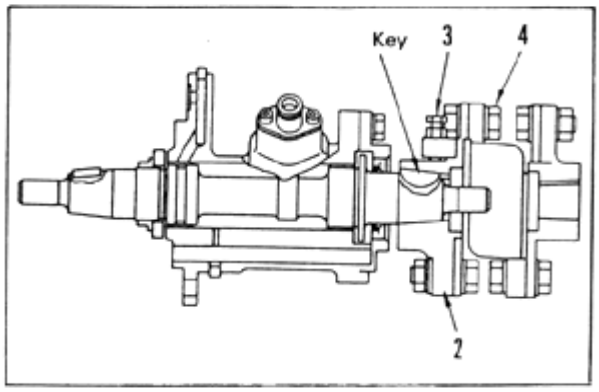


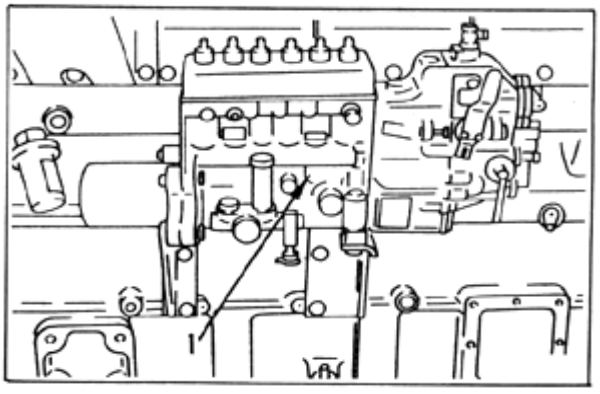
4) Install connection (3).
5) Install turbocharger lubrication tube (2).
6) Install spill tube (1).

36. Fuel injection pump assembly

- Laminated coupling type

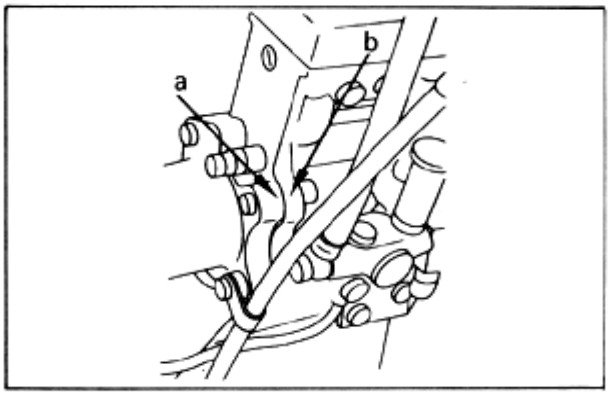
1) Knock key into drive shaft.
2) Screw lifting tool **B** into delivery valve thread, raise fuel injection pump assembly (1), then align key groove of pump coupling (2), and connect pump.
3) Tighten drive shaft mounting bolts (3) of coupling.
4) Align lines on coupling and bearing cover of injection pump, then tighten bolt (4).
   - ★ If the mounting bolts are not tightened uniformly, the pump will be at an angle and will rotate against the drive shaft, and this will result in a change in the injection timing.
   - ★ If there are no lines marked, or if the injection pump has been replaced, adjust the injection timing. For details, see TESTING AND ADJUSTING..





- Flange type
  - ★ When installing the flange type injection pump, align line "a" on the flange with line "b" on the injection pump flanges.
  - ★ If there are no lines marked, or if the injection pump has been replaced, adjust the injection timing. For details, see TESTING AND ADJUSTING.

1) Fit gasket, then install lubrication tube between injection pump and cylinder block.



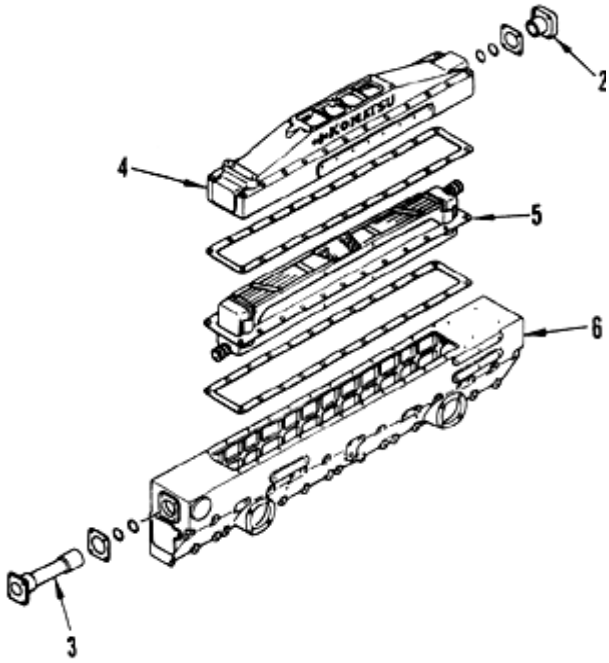
37. Aftercooler, intake manifold assembly

- Assemble aftercooler and intake manifold assembly.
  - i) Fit gasket, then assemble core assembly (5) to intake manifold (6).
  - ii) Fit gasket, then install cover (4).

kgm Mounting bolt: 30 ± 0.5 kgm

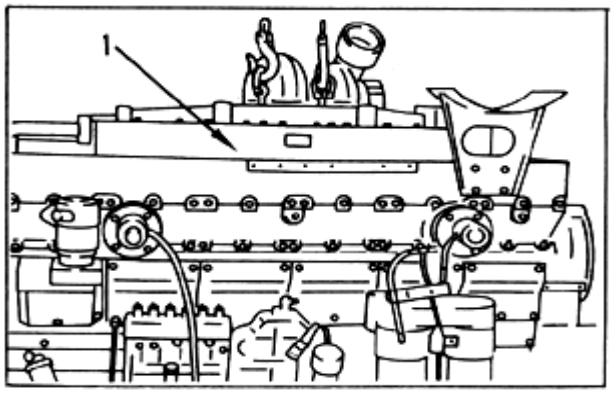
  - iii) Fit gasket and O-ring, then align connector (3) and joint (2) with joint of cooler core, and install.

O-ring: Engine oil (SAE #30)



1) Fit gasket, then install aftercooler and intake manifold assembly (1).

kgm Mounting bolt : 6.5 ± 1.0 kgm



38. Turbocharger, exhaust manifold assembly

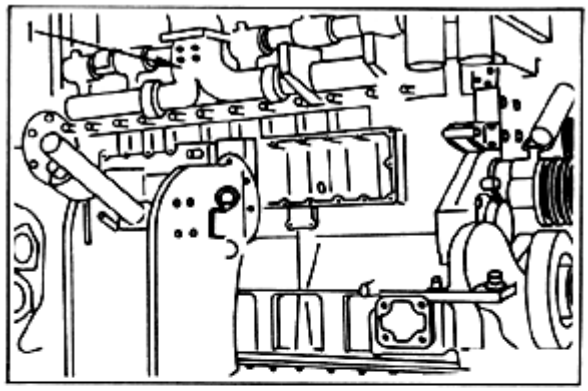
Fit gasket, then install turbocharger and exhaust manifold assembly (1).

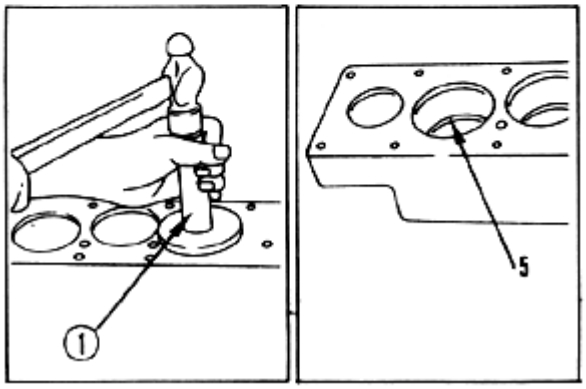
Mounting bolt thread:
Anti-friction compound (LM-P)

Mounting bolt: 11.25 ± 1.25 kgm

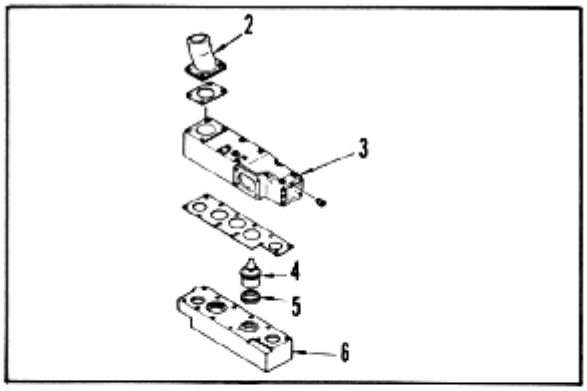
BD375A,BE1000,WA700,BD465-5
2 bolts (length: 50 mm):8.5 ± 0.5 kgm

★ If the turbocharger has been replaced, the tightening torque for the turbocharger mounting bolts is as follows.





- BE1000 : 60 - 7.5 kgm
  (Serial No. up to 12887)
  : 4.5 - 5.5 kgm
  (Serial No. 12888 & up)

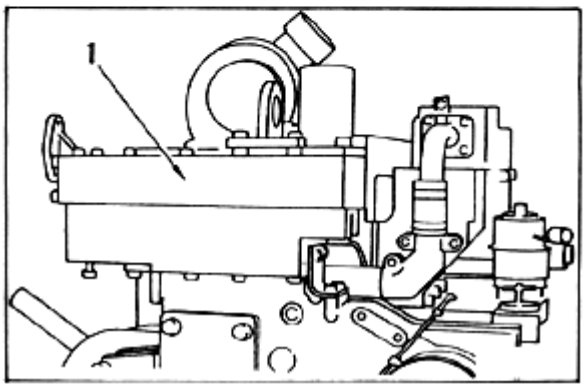


39. Thermostat case

Assemble thermostat case.

i) Using push tool①, press fit thermostat seal (5) to housing (6).
   ★ Be careful that the seal is not at an angle when press fitting.
ii) Assemble thermostat (4).
iii) Fit gasket, then install cover (3) and outlet pipe (2).

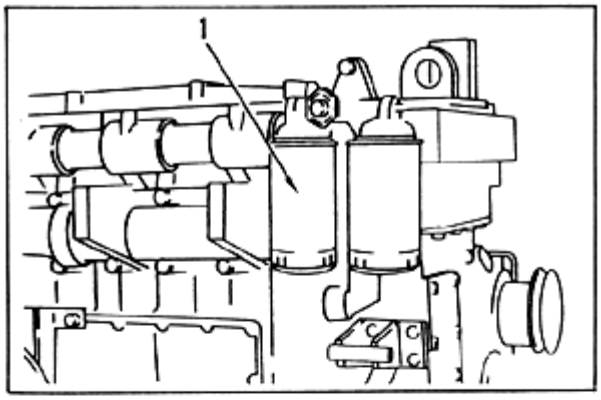
Install thermostat case (1).



40. Corrosion resistor

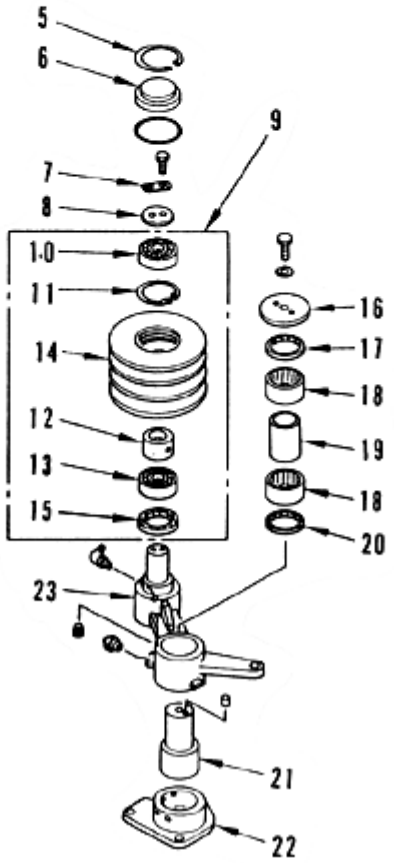
Install corrosion resistor (1).

- ★ Coat the seal and thread with engine oil (SAE #30).
- ★ After the seal surface comes into contact with the fitter head,tighten a further 2/3 turns.

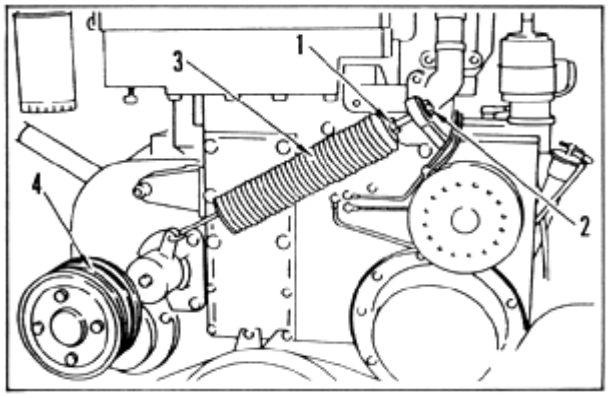


41. Tension spring, tension pulley

- Assemble tension pulley.
  - i) Press fit shaft (21) to bracket (22).
  - ii) Install seal (20) to bracket (23), then assemble inner race (19), bearing (18), and seal (17), and install plate (16).
    - ★ Coat the bearing and seal portion with grease (G2-LI).
  - iii) Install oil seal (15) to pulley (14).
  - iv) Assemble pulley to bracket (23), then assemble bearing (13) and spacer (12), and install snap ring (11).
  - v) Install braring (10).
  - vi) Fit holder (8), and tighten lock plate (7) with bolts.
    - ★ Bend the lock plate securely.
  - vii) Fit cover (6), then secure with snap ring (5).

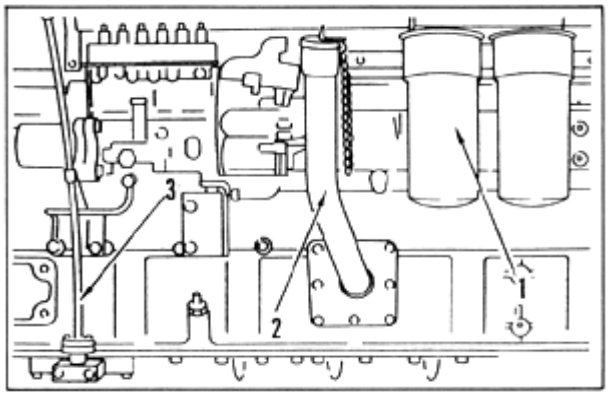


1) Insert spacer, then install tension pulley assembly (4) and bracket as one unit.
2) Install tension spring (3) and tighten bolt (2), then secure them with locknut (1).
   ★ The tension spring will be adjusted according to the tension of the fan belt after the engine assembly is mounted.



42. Oil filter, oil level gauge

1) Fit gasket and install oil level gauge (3).
2) Fit gasket and install oil filter (2).



43. Oil filter

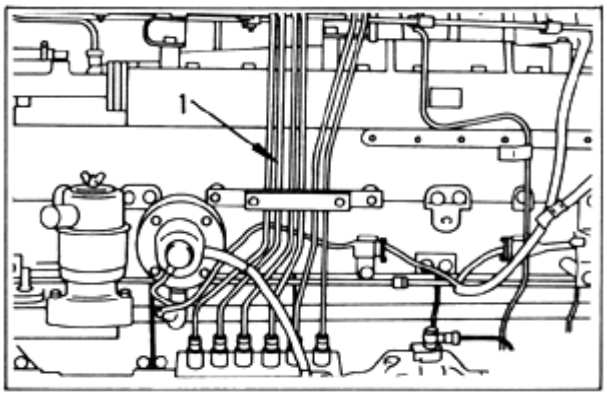
Fit O-ring and install bracket, then install oil filter (1).

★ Coat the seal and thread with engine oil (SAE #30).
★ After the seal surface comes into contract with the filter head, tighten by hand a further 3/4 1turn.

44. Fuel injection tube

Install fuel injection tube (1) and secure it with the clamp.

kgm Sleeve nut: 2.25 ± 0.25 kgm
(both pump and nozzle ends)

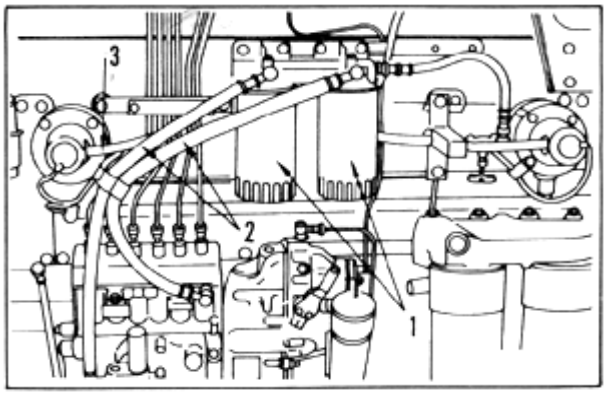


45. After-cooler tube and oil filter tube

1) Install lubrication tube for the turbocharger.
2) Install O-ring and after-cooler tube, then secure them with the lockbolt.

46. Fuel filter

1) Install fuel filter (1).
2) Fit gasket and connect fuel hoses (2).
3) Connect fuel hose (3) for APS.



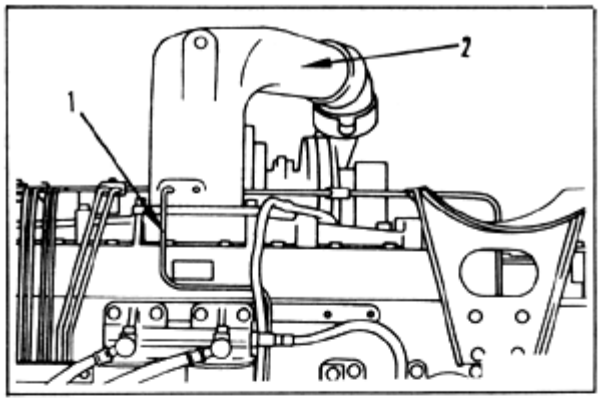
47. Connector pipe

1) Install O-ring and gasket, install connector pipe (2), then secure it with the plate.

O-ring : Grease (G2-LI)

★ When connecting the piping to the turbocharger, center the piping so that the turbocharger is not twisted, then tighten.

2) Fit gasket and install tube (1) for boost compensator.

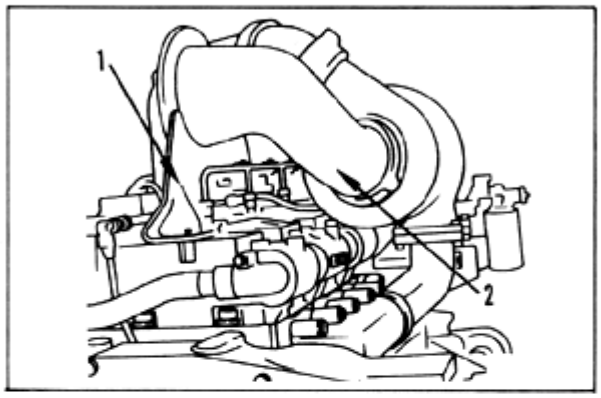


48. Intake connector

Fit O-ring and install intake connector (2). Align the hole on it with the one on bracket (1).

O-ring : Grease (G2-LI)

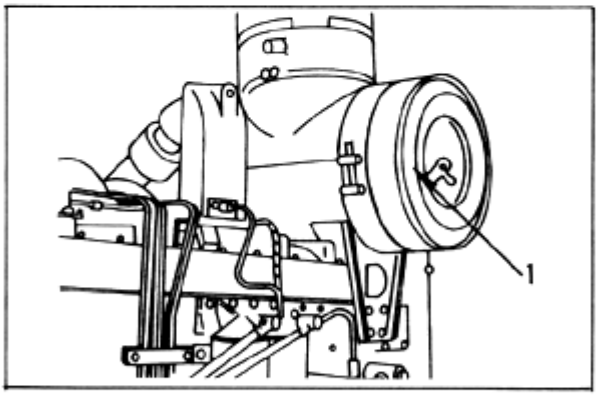
★ Insert a plain washer between the connector and the bracket.



49. Air cleaner assembly

Fit gasket and install air cleaner assembly (1) and secure it with the band.

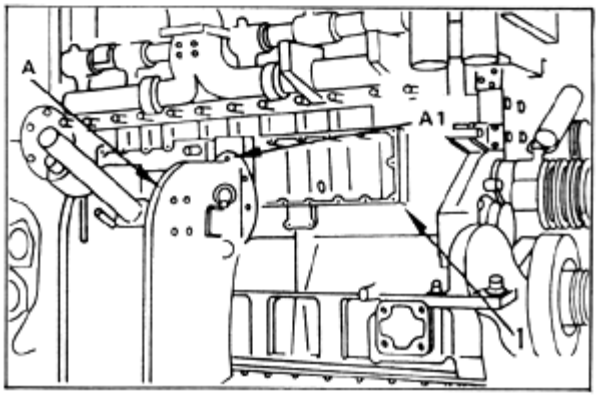
kgm Band : 1.0 ± 0.1 kgm



50. Setting off engine from engine stand

1) Lift the engine assembly (1) and remove the mounting bolts to separate the engine assembly from engine repair stand **A**.
2) Remove the bracket for the engine repair stand **A1**.

★ Prepare an engine stand, then place the engine on the stand and secure it in position.

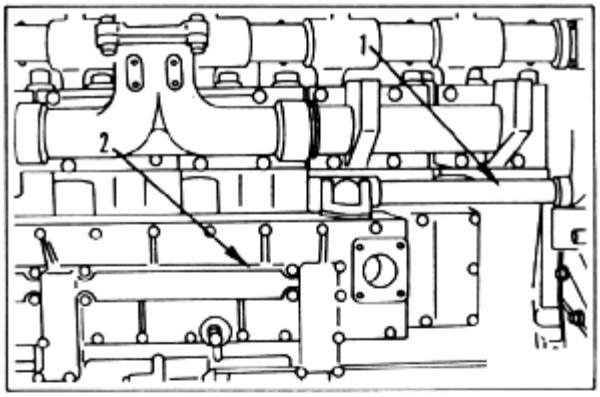


51. Oil cooler

1) Fit gasket and install oil cooler (2).

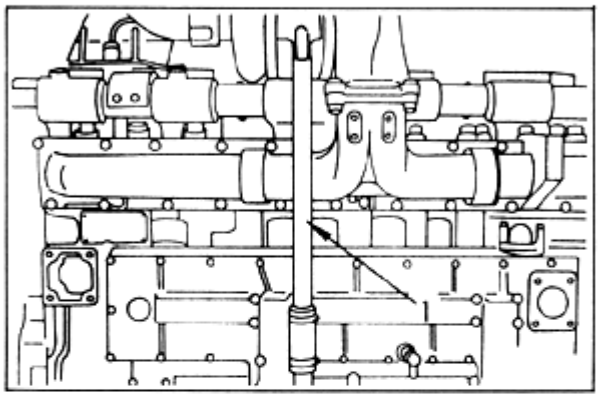
kgm Oil cooler mounting bolt :
6.75 ± 0.75 kgm

2) Fit gasket and install water pipe (1).



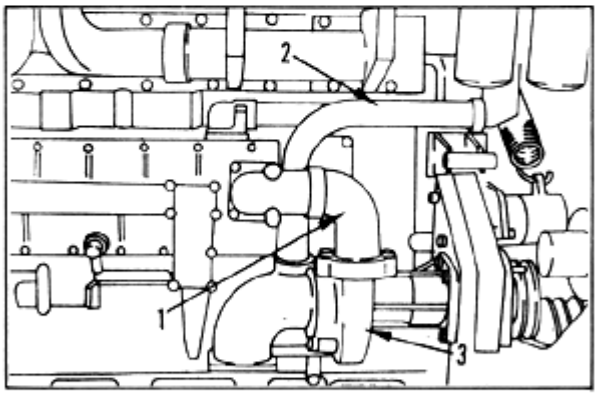
52. Drain tube of turbocharger

Fit gasket to both end faces, then install drain tube (1) for the turbocharger.



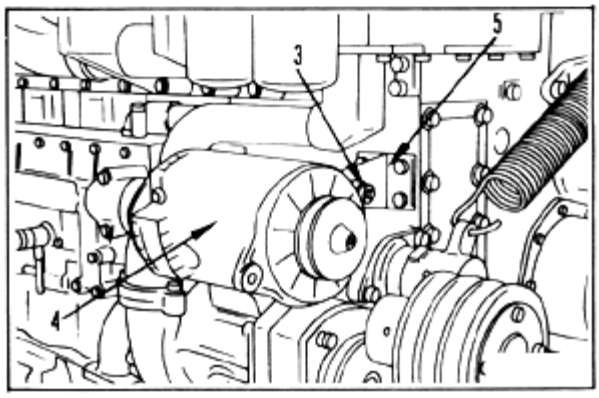
53. Water pump assembly

1) Install drive shaft
2) Fit gasket and install water pump assembly (3), aligning it with the drive shaft.
3) Fit O-rings to both end faces. Install water pipe (2) and secure it with the plate.
4) Fit O-rings and gaskets to both end surfaces, then install water pipe (1).

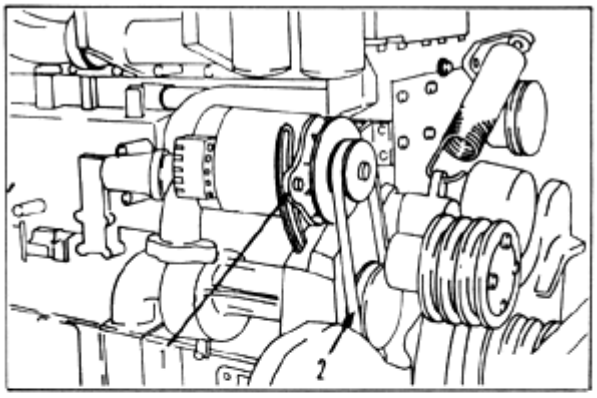


54. Alternator assembly

1) Install bracket (5).
2) Install alternator (4) and temporarily tighten nut (3).

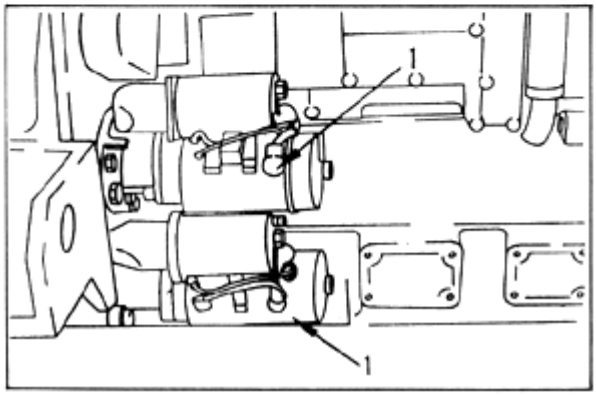


3) Fit belt (2) to the pulley, and tighten the mounting bolts for adjustment plate (1).
4) Raise the alternator assembly with a bar, and adjust so that the deflection of the belt is approx. 15 mm when pressing its center with 6 kg of force. Then tighten the bolt securely.



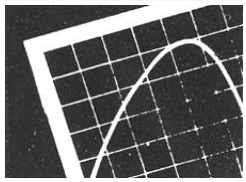
55. Starting motor assembly

1) Fit gasket and install starting motor (1).



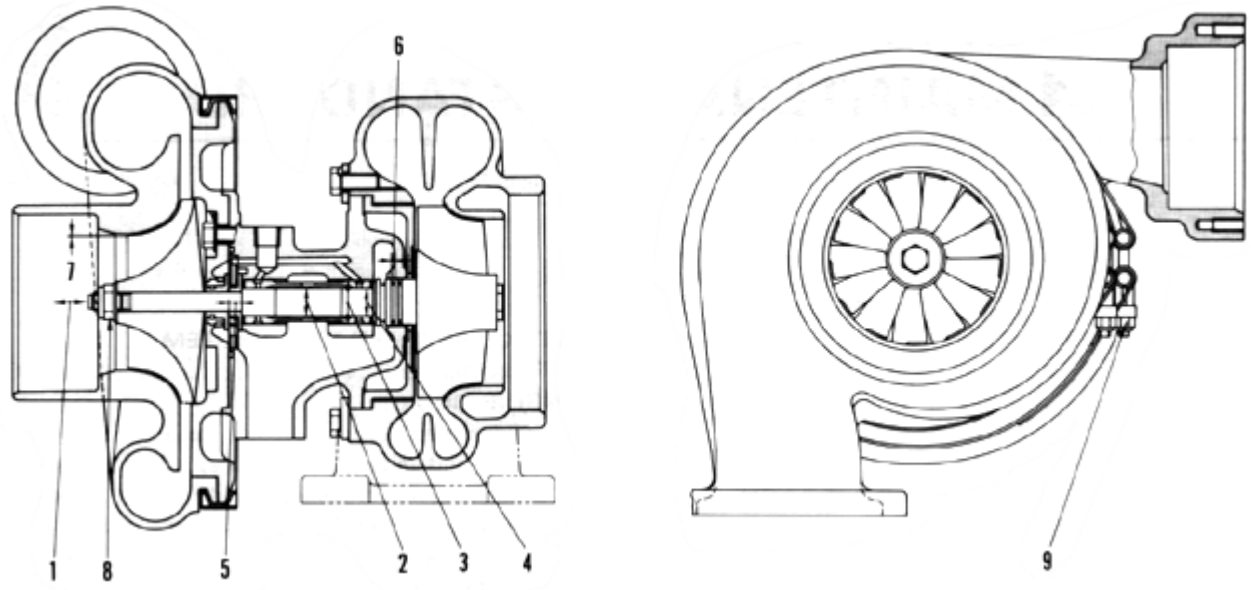
ENGINE

15 MAINTENANCE STANDARD



TURBOCHARGER

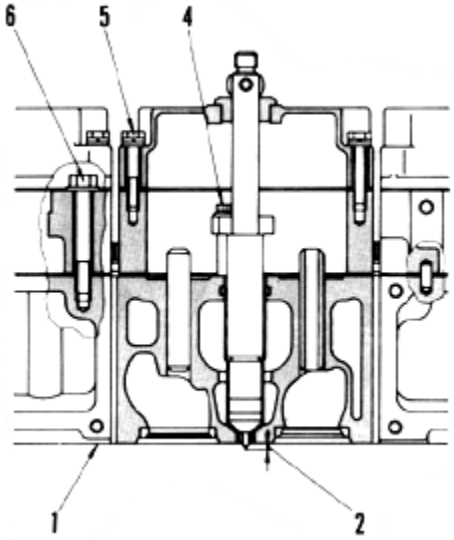
KTR110



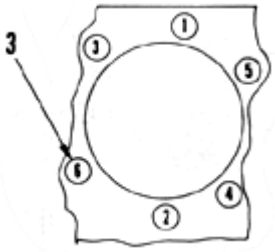
Unit: kgm

No.	Check item		Criteria		Remedy
1	End play (Play in axial direction)		Permissible range 0.08 - 0.18		Replace parts related to thrust
2	Radial play (Play in radial direction)		0.25 - 0.60		Replace parts related to bearing
3	Outside diameter of journal bearing inside diameter of center housing		Permissible range		
			Shaft	Hole	
			22.92 - 22.96	23.00 - 23.03	
4	Inside diameter of journal bearing, outside diameter of thrust collar		14.95 - 14.97	15.00 - 15.04	
5	Thickness of thrust bearing		Permissible range		Replace
			Width	Groove	
			4.86 - 4.92	5.00 - 5.04	
6	Thickness of seal ring	Turbine end	1.85 - 1.92	1.46 - 2.05	
		Blower	1.45 - 1.52	1.56 - 1.65	
7	Clearance between blower housing and impeller		Clearance limit: (Min.) 0.20		Replaces parts related to bearing
8	Tightening torque of blower impeller locknut		2.9 ± 0.3 kgm		Tighten
9	Tightening torque of V-band locknut		0.9 ± 0.1 kgm		

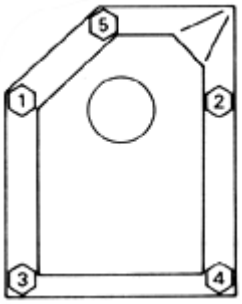
CYLINDER HEAD



Tightening order of head mounting bolt



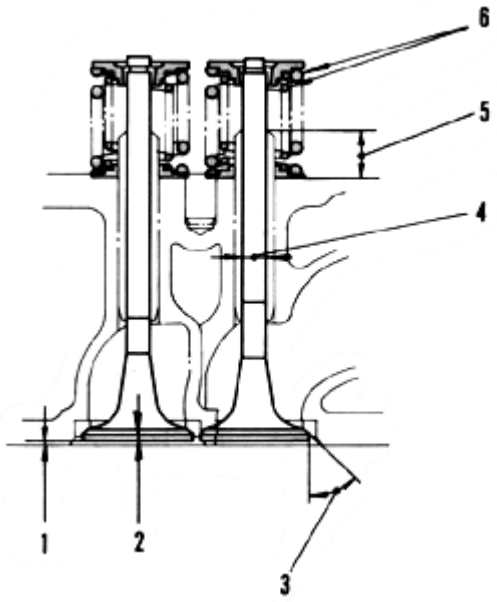
Tightening order of head cover mounting bolt



Uunit: mm

No.	Check item	Criteria			Remedy
1	Distortion of cylinder head mounting surface	Tolerance		Repair limit	Repir by grinding or replace
		Max.0.05		0.1	
2	Protrusions of nozzles	Standard: 4.9 to 5.7			Replace nozzle sleeves
3	Tightening torque of cylinder head mounting bolts (Coat bolt threads and washer with anti-friction Compound (LM-P))	Order	Target valve (kgm)	Range (kgm)	Tighten in sequence as indicated above.
		1st	8.0	6.5 to 9.5	
		2nd	23.5	22.0 to 25.0	
		3rd	39.0	37.5 to 40.5	
		4th	50.5	49.0 to 52	
4	Tightening torque of nozzle holder mounting bolt	Target value (kgm)		Range (kgm)	Retighten
		2.75		2.5 to 3.0	
5	Tightening torque of cylinder head cover	3.25		3.0 to 3.5	
6	Tightening torque of rocker arm housing mounting bolt	10		9.5 - 10.5	

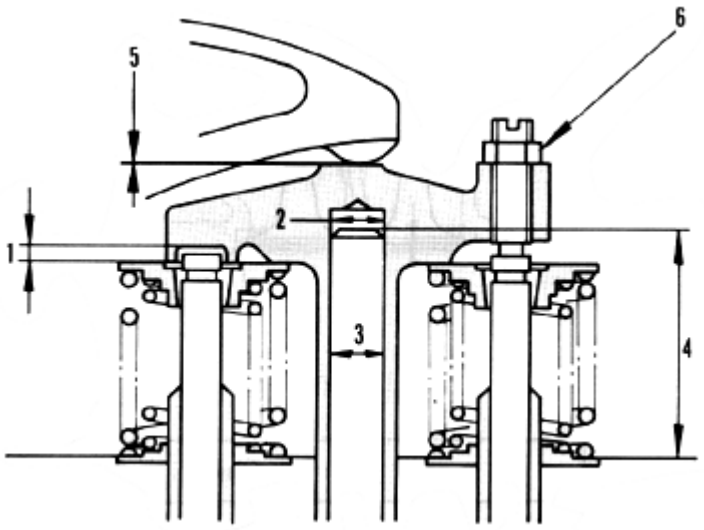
ALVES AND VALVE GUIDE



unit: mm

No.	Check item		Criteria				Remedy
1	Amount of valve sinking			Standard		Repair limit	Replace valve or seat
		Intake valve		0.9 - 1.5		2.1	
		Exhaust valve					
2	Valve head thickness			Standard size	Tolerance	Repair limit	
		Intake valve		3.4		2.9	Replace valve
		Exhaust valve		3.5		3.1	
3	Valve seat angle			Standard		Tolerance	
		Intake vlave		60°		±0°10’	
		Exhaust vlave		45°		±0°10’	
4	Outside dianeter of valve stem	Intake	Standard size	Tolerance		Repair limit	Replace
			12	-0.060 -0.080		11.90	
		Exhaust		-0.092 -0.107		11.80	
	Inside diameter of valve guide		12	-0.001 -0.019		12.10	
5	Protrusion of valve guide		23.7	+0.2 -0.3		-	
6	Valve		Free length	Installed length	Installed load	Load limit	Replace
	Close	Inner	59.3	47.0	19.07 ± 1 kg	17.4 kg	
		Outer	64.8	52.0	43.78 ± 2 kg	39.9 kg	
	Open	Inner	59.3	32.5	41.55 ± 2 kg	37.8 kg	
		Outer	64.8	37.5	93.23 ± 4.7 kg	84.8 kg	
	Squareness of valve spring		Inner spring	Repair limits: 2°			
	Outer spring						

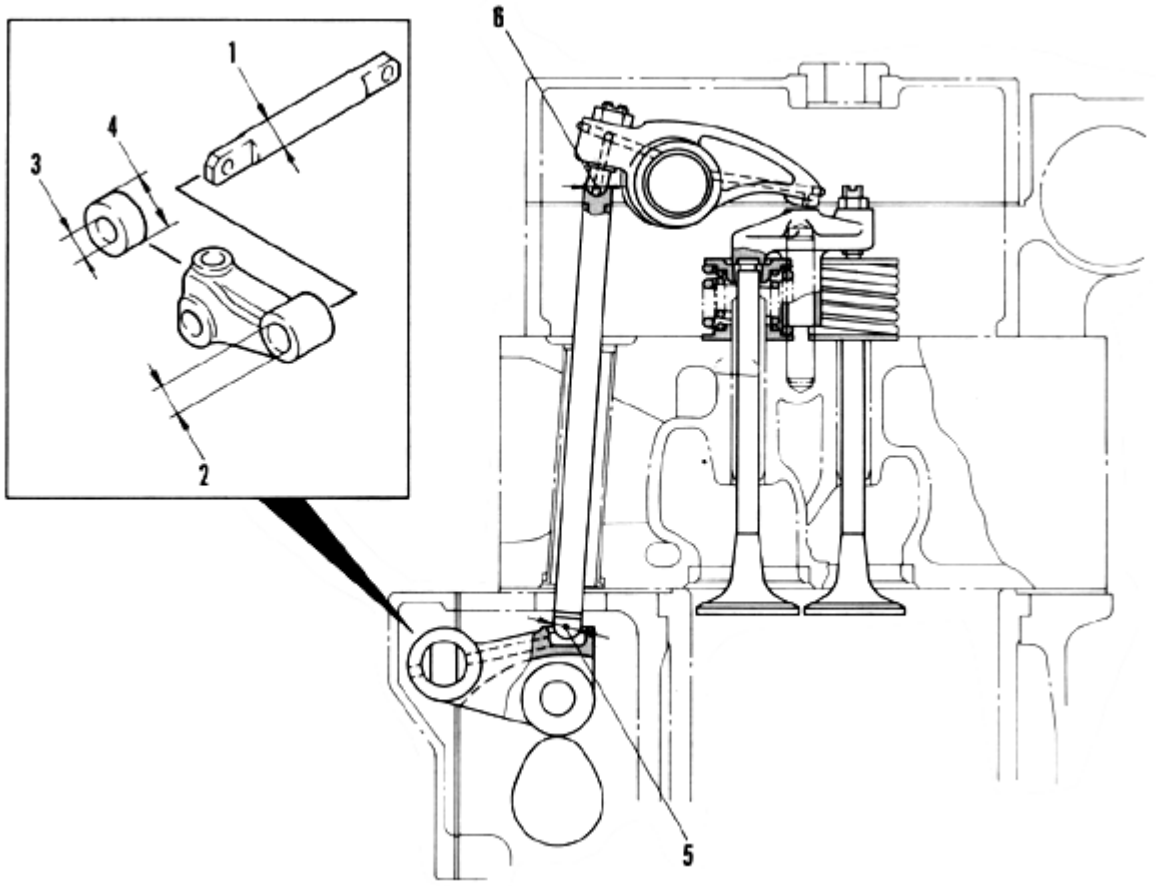
CROSSHEAD AND CROSSHEAD GUIDE



unit: mm

No.	Check item		Criteria			Remedy
1	Depth of cross head stem	Except BD465-5	Standard size: 3.0	Tolerance: +0.3 0	Repair limit: -	Replace
		BD465-5 only	Standard size: 7.5	Tolerance: +0.3 0	Repair limit: -	
2	Inside diameter of crosshead		Standard size: 15	Tolerance: +0.10 +0.05	Repair limit: 15.21	
3	Outside diameter of crosshead guide		Standard size: 15	Tolerance: +0.039 +0.028	Repair limit: 15.00	
3	Clearance between crosshead guide and crosshead		Standard clearance: 0.011 to 0.072		Clearance limit Adjust: 0.02	
4	Protrusion of crossgead guide		Standard size: 54	Tolerance: 0 -0.3	Repair limit: -	Replace
5	Valve clearance (at cold)		Intake valve: 0.4		Exhaust valve: 1.0	
6	Tightening torque of cross-head lock nut		Except BHD465-5		4.0 ± 0.6 kgm	Tighten
			BHD465-5 only (Serial No. 14203 and up)		6.0 ± 0.6 kgm	

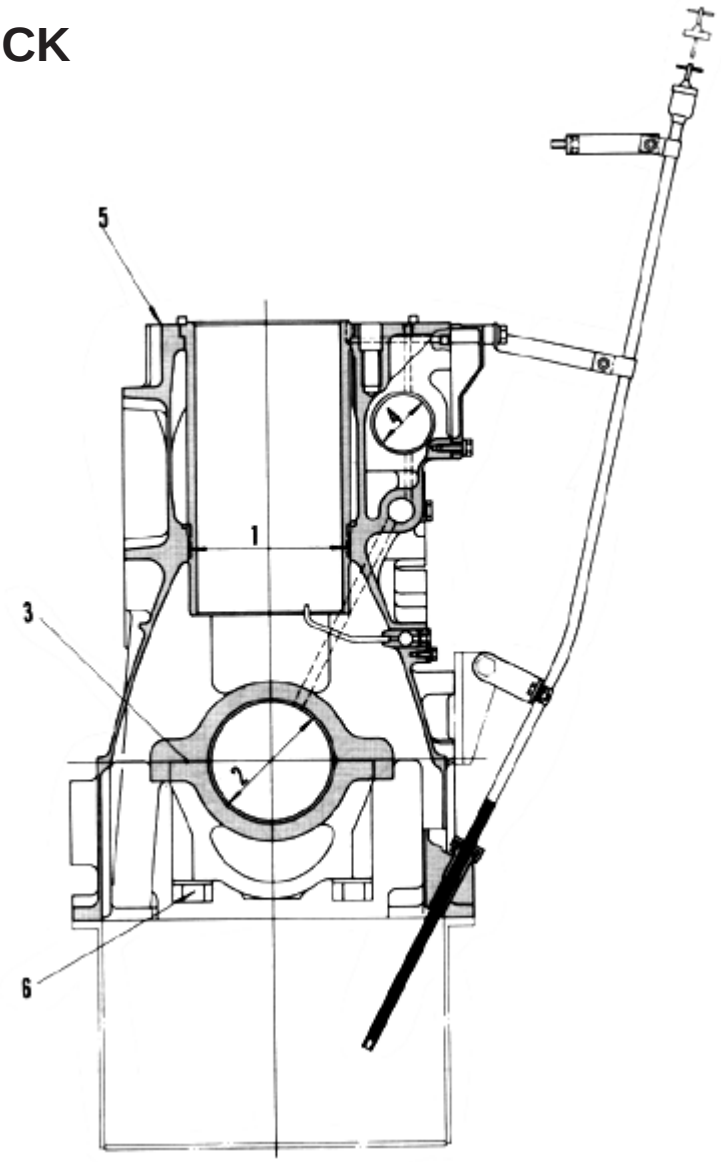
PUSH ROD AND CAM FOLLOWER



unit: mm

No.	Check item	Criteria			Remedy
1	Outside diameter of cam follower shaft	Standard size	Tolerance	Repair limit	Replace
		25.0	-0.040 -0.055	24.9	
2	Inside diameter of cam follower lever	25.0	-0.020 0	25.0	
3	Inside diameter of cam follower roller	19.0	+0.175 +0.150	19.2	
	Outside diameter of cam follower roller pin	19.0	+0.075 +0.065	19.0	
4	Outside diameter of cam follower roller	41.0	+0.050	41.0	
			+0.025	-	
5	Diameter of push rod tip ball	15.85	± 0.03	-	
6	Inside diameter of push rod socket	12.7	± 0.20	-	

CYLINDER BLOCK



unit: mm

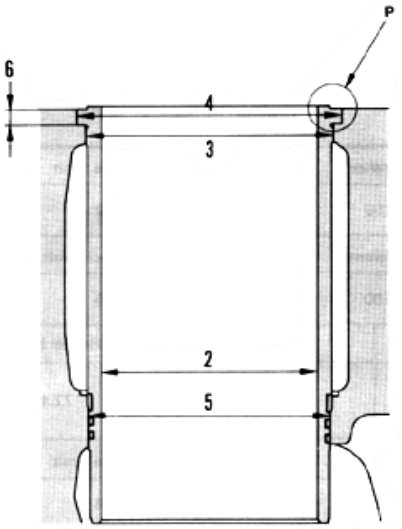
No.	Check item	Criteria					Remedy
			Tolerance				
1	Clearance between cylinder block and liner	Standard size	Inside diameter of block	Outside diameter of liner	Standard clearance	Clearance limit	Replace cylinder liner or block
		190			0.050 to 0.160		

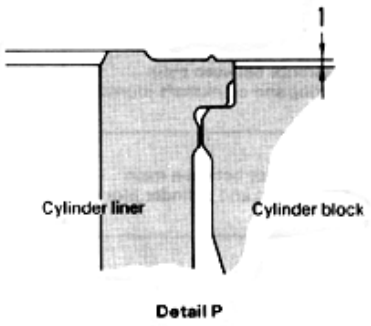
No.	Check item	Criteria			Remedy
		Standard size	Tolerance	Repair limit	
2	Inside diameter of main bearing hole	148	-0.025 0	-	Repair or replace
	Thickness of main bearing	4	-0.040 -0.050	3.90	
	Inside diameter of main bearing	140	+0.125 +0.075	140.20	

unit: mm

No.	Check item	Criteria			Remedy
3	Clearance between main bearing and crankshaft journal	Standard clearance	Clearance limit		
		0.075 to 0.150	0.32		
4	Interference between main bearing cap and cylinder block	Standard interference	Interferencelimit		
		0.080 to 0.1.60	0.05		
5	Inside diameter of camshaft bushing	Standard size	Tolerance	Repair limit	Repair or replace
		72	+0.070 0	72.10	
	Clearance between camshaft and journal	Standard clearance	Clearance limit		
		0.080 to 0.180	0.24		
6	Distortion of cylinder head face	Tolerance	Repair limit		
		0.09	0.15		
7	Tightening torque of main bearing cap bolt (Coat bolt threads with engine oil)	Order	Target value (kgm)	Range (kgm)	Tighten
		1st	56	51 to 61	
		2nd	113	107 to 118	
		3rd	Loosen completely		
		4th	38	33 to 43	
		5th	75	70 to 80	
		6th	113	107 to 118	

CYLINDER LINER

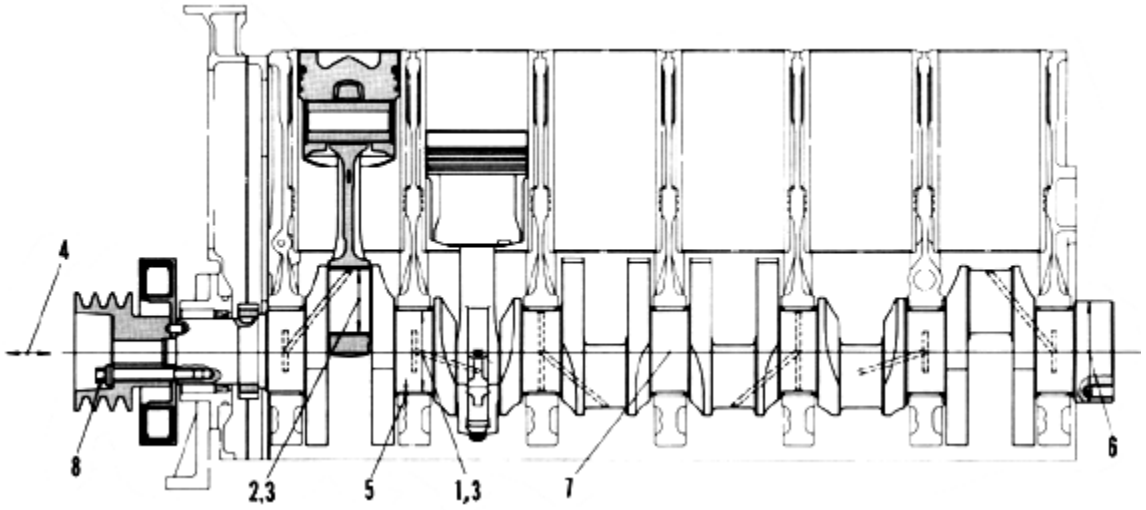




unit: mm

No.	Check item	Criteria			Remedy
1	Protrusion of cyliner liner	Permissible renge: 0.07 to 0.15 Difference among cylinder: 0.05 max.			Replace inder liner or block
2	Inside diameter of cylinder liner	Standard size	Tolerance	Repair limit	Replace cylinder liner
		170	+0.04 0	170.24	
	Roundness	Repair limit: 0.020			
	Cylindricity	Repair limit: 0.015			
3	Outside diameter of cylinder liner (Counter bore lower part)	Standard size	Tolerance		
		194.59	194.565 - 194.615		
	Interference of cylinder liner and block (Counter bore lower part)	Standard interference: 0.025 to 0.135			
4	Outside diameter of cylinder liner (Counter bore part)	Standard size	Tolerance		
		205.99	205.965 - 206.015		
	Clearance between cylinder liner and block (Counter bore part)	Interference: 0.085 to Clearance: 0.025			
5	Outside diameter of cylinder liner (O-ring part)	Standard size	Tolerance		
		190.4	190.34 - 190.40		
	Clearance between cylinder liner and block (O-ring part)	Standard clearance: 0.050 to 0.210			
6	Unevenness of counter bore depth	Tolerance	Repair limit		Repair by grinding
		-	0.03		

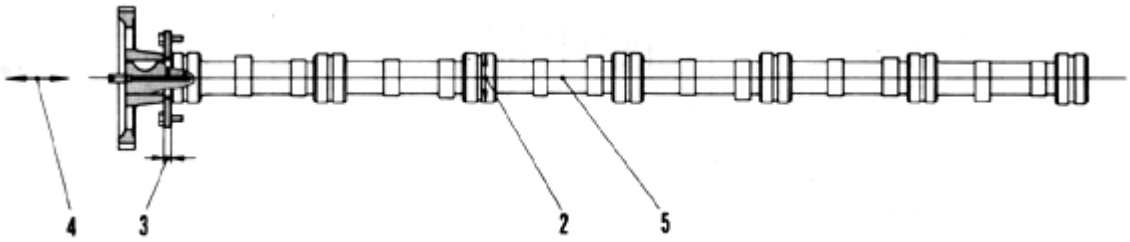
CRNAKSHAFT



unit: mm

No.	Check item	Criteria				Remedy
		Size	Standard size	Tolerance	Repair limit	
1	Outside diameter of main journal	S.T.D.	140.00	0 -0.025	139.91	Repair or replace
		0.25US	139.75		139.66	
		0.50US	139.50		139.41	
		0.75US	139.25		139.16	
		1.00US	139.00		138.91	
2	Outside diameter of crank pin journal	S.T.D.	108.00	0 -0.020	107.91	
		0.25US	107.75		107.66	
		0.50US	107.50		107.41	
		0.75US	107.25		107.16	
		1.00US	107.00		106.91	
3	Journal roundness		Standard		Repair limit	Replace
		Main journal	max. 0.010		0.085	
		Pin journal	max. 0.010		0.065	
4	End play	Tolerance			Repair limit	
		0.140 to 0.320			0.69	
5	Main bearing thickness(Center)	Standard size	Tolerance		Standard interference	
		4	-0.040 -0.050		3.90	
6	Outside diameter of rear flange	170	±0.020		-	
7	Bend of crankshaft (by indicator)	Tolerance			Repair limit	
		0.09			0.20	
8	Tightening torque of crank pulley mounting bolt	See page14-047				Tighten

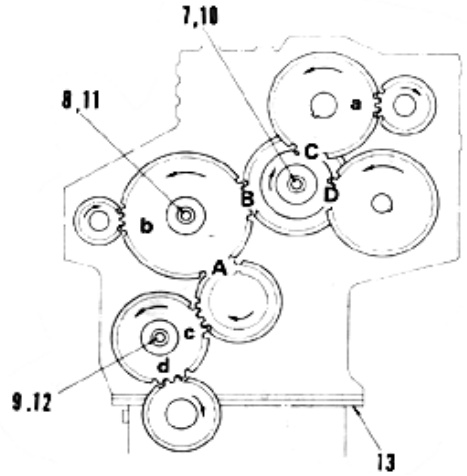
CAMSHAFT



unit: mm

No.	Check item		Criteria			Remedy
			Standard size	Tolerance	Repair limit	
1	Cam height	Intake side	62	+0.440 +0.240	61.37	Repair or replace
		Exhaust side	61	-0.310 -0.510	59.64	
2	Outside diameter of journal		72.00	-0.080 -0.110	71.86	Replace
3	Thrust plate thickness		10.00	-0.025 -0.060	6.85	
4	Camshaft end play		Standard clearance		Clearance limit	Replace thrust plate
			0.075 to 0.240		0.40	
5	Bend of camshaft		Repair limit: 0.20 (by indicator)			Replace

TIMING GEAR

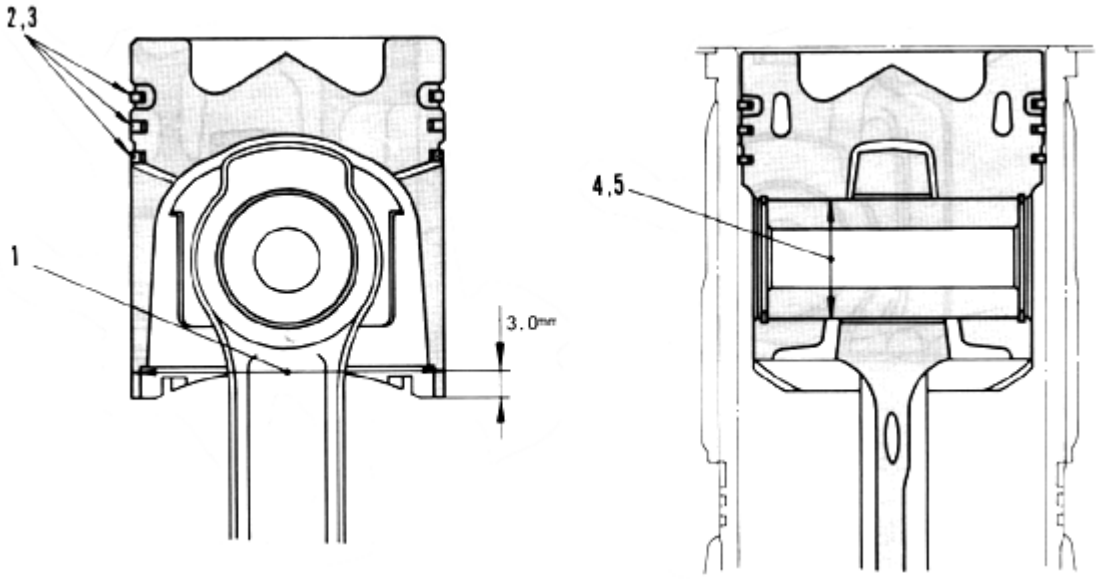


Unit : mm

No.	Check item	Criteria					Remedy
		Position	Measuring point		Standard	Repair limit	Replace
		A	Crank gear and idler gear		0.14 to 0.46		
		B	Main idler gear (large) and idler gear		0.013 to 0.47		
		C	Main idler gear (small) and cam gear		0.13 to 0.47		
		D	Main idler gear (small) and injection pump gear		10 to 0.50		
		a	Cam gear and compressor drive gear				
		b	Water pump idler gear and water drive gear		0.095 to 0.46		
		c	Crank gear and oil pump idler gear		0.12 to 0.425		
		d	Oil pump idler gear and oil pump drive gear		0.10 to 0.445		
7	Clearance between main idler gear bushing and shaft	Standard size	Tolerance		Stadard Clearance	Clearance limit	Replace bushing
			Shaft	Hole			
		47	+0.600 +0.585	+0.695 +0.630	0.045 to 0.095		
8	Clearance between idler gear bushing and shaft	47	+0.600 +0.585	+0.695 +0.630	0.045 to 0.095		
9	Clarance between oil pump idler gear bushing and sahft	47	+0.600 +0.585	+0.695 +0.630	0.045 to 0.095		
10	End play of main idler gear	Standard clearance			Clearance limit		Replace thrust bearing
		0.10 to 0.32					
11	End play of idler gear	0.10 to 0.32					
12	End play of oil pump idler gear	0.10 to 0.32					
13	Difference of timing gear case and cylinder block lower step	Tolerance: 0.15					Replair or replace

PISTON, PISTON RING AND PISTON PIN

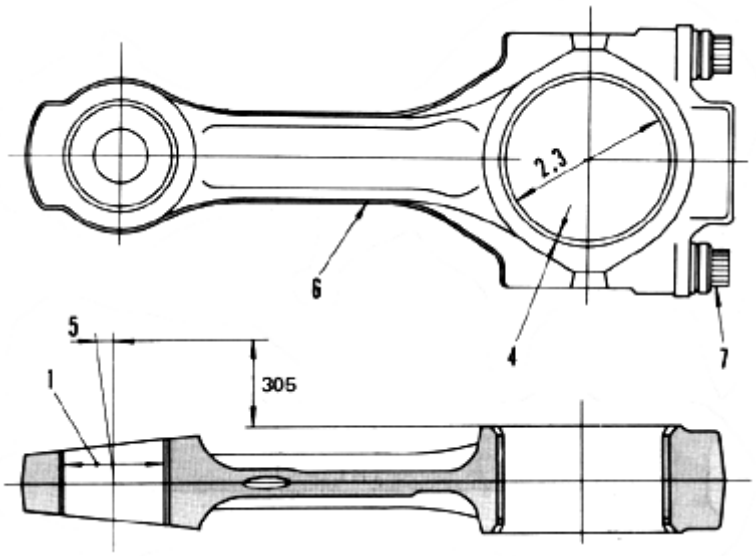
ALUMINIUM PISTON TYPE



unit: mm

No.	Check item	Criteria					Remedy
1	Outside diameter of piston (3.0 mm from bottom and at 20° C)	Standard size: 170		Tolerance: -0.257 / -0.287		Repair limit: 169.62	Replace
2	Piston ring groove		Standard size	Tolerace: Ring groove	Tolerace: Ring thickness	Clearance limit	
		Top ring	Keystone	Check with piston groove wear gauge		0.15 Clearance with new ring	
		2nd ring	Keystone				
		Oil ring	4.80	±0.010	-0.500 / -0.075	0.3	
3	Piston ring gap			Standard clearance		Clearance limit	
		Top ring		0.50 - 0.65		1.8	
		2nd ring		0.45 - 0.60			
		Oil ring		0.50 - 0.70			
4	Inside diameter of piston pin boss	Standard size: 68		Tolerance: +0.014 / +0.004		Repair limit: 68.04	
5	Outside diameter of piston pin	68		0 / -0.006		67.98	

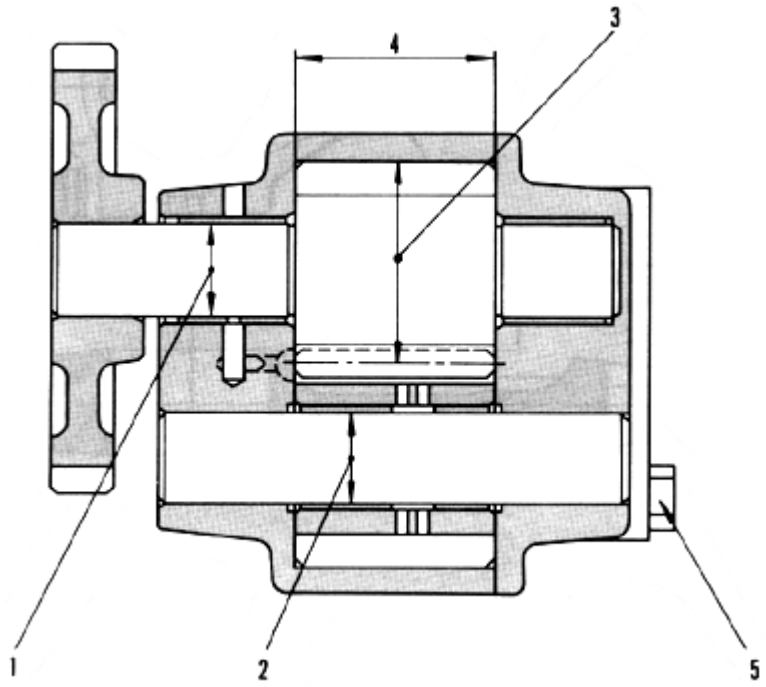
CONNECTING ROD



unit: mm

No.	Check item	Criteria					Remedy
1	Clearance betwen connecting rod bushing and piston pin	Standard size	Tolerance		Standard Clearance	Clearance limit	Replace (the bushing is supplied as a semi-finished Product)
			Shaft	Hole			
		68	0 -0.060	+0.070 +0.050	0.050 - 0.075	0.11	
2	Inside diameter of connecting rod big end	Standard size		Tolerance			
		115		+0.025 0			
3	Clearance between inside diameter of connecting rod big end and crankshaft journal	Standard clearance		Clearance limit			
		0.060 - 0.130		0.34			
4	Connecting rod bearing thickness (Center)	Size	Standard size	Tolerance		Repair limit	
		S.T.D.	3.500			3.41	
		0.125US	3.625	-0.040		3.54	
		0.250US	3.750	-0.030		3.66	
		0.375US	3.875			3.79	
		0.500US	4.000			3.90	
5	Bend or twist of connecting rod	Repair limit of bend: 0.10 Repair limit of twist: 0.25					
6	Connecting rod weight	10.15 ± 0.03 kg					
7	Tightening torque of connecting rod cap (Coat bolt and nut threads with engine oil)	Order	Target (kgm)	Range (kgm)			Tighten
		1st	20	19 - 21			
		2nd	90°	90° -105			

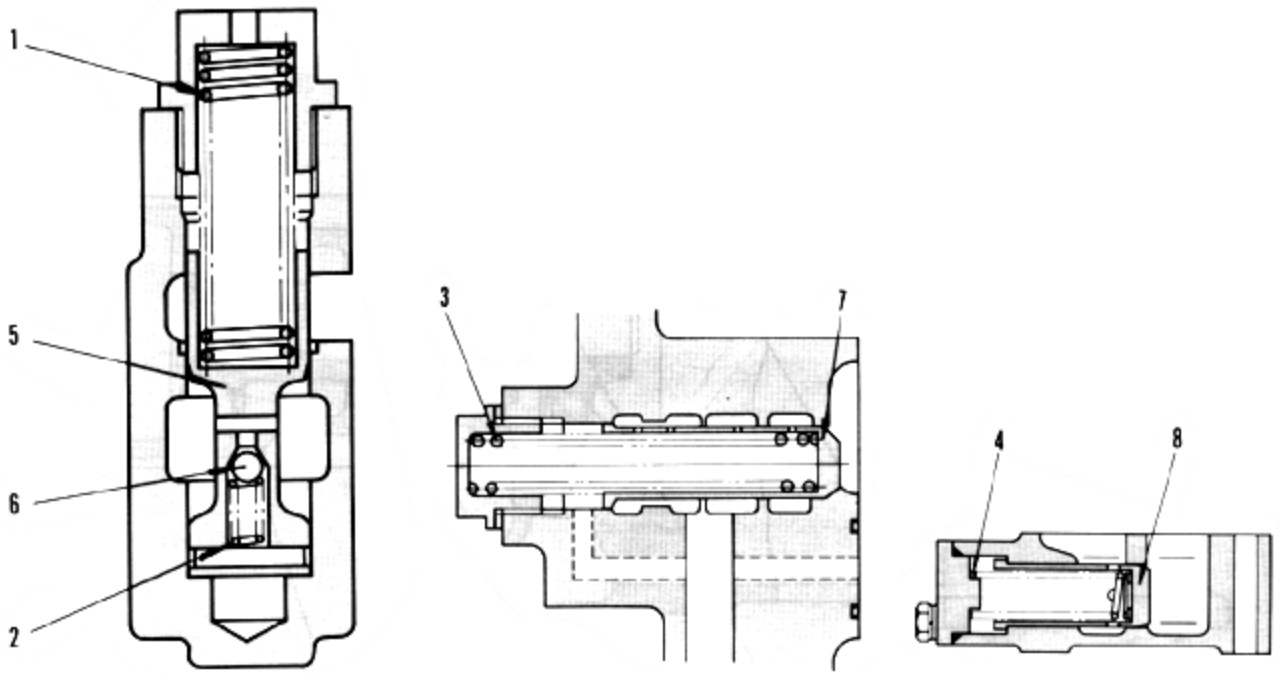
OIL PUMP



unit: mm

No.	Check item	Criteria					Remedy
		Standard size	Tolerance		Standard Clearance	Clearance limit	
			Shaft	Hole			
1	Clearance between drive shaft and bushing	32	-0.025 -0.040	+0.035 +0.015	0.040 to 0.075	-	
2	Clearance between driven shaft and driven gear bushing	30	-0.020 -0.035	+0.030 +0.010	0.030 to 0.070		Replace
3	Clearance between outside diameter of gear and body	71.95	0 -0.030	+0.170 +0.120	0.085 to 0.125		
4	Main pump gear and body end play	66	-0.095 -0.115	+0.035	0.095 to 0.15		
5	Tightening torque of mounting bolt	69 ± 1.0 kgm					Tighten

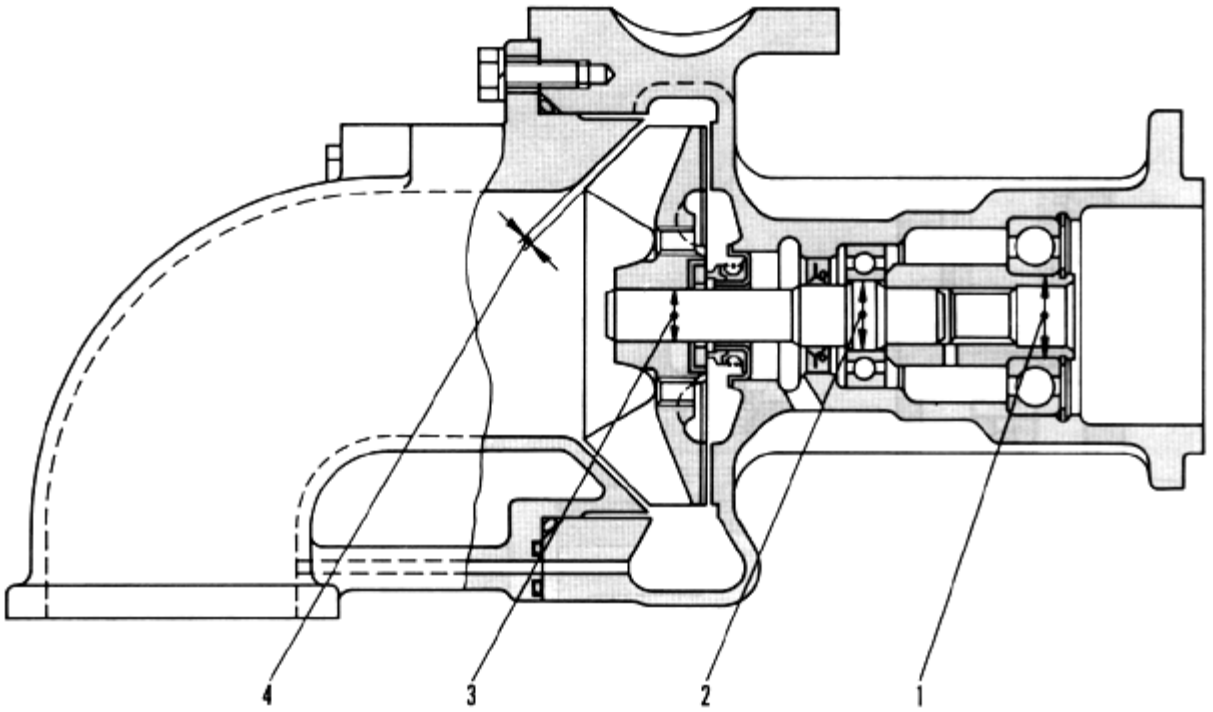
OIL PUMP RELIEF VALVE, PISTON COOLING VALVE AND OIL COOLER BY-PASS VALVE



unit: mm

No.	Check item	Criteria					Remedy
		Standard size			Repair limit		
1	Main relief valve spring	Free length	Installed length	Installed load	Free length	Installed load	
		73.77	72.0	2.37 kg			
2	Regulator valve spring	21.5	17.6	2.97 kg			
3	Piston cooling valve spring (Check valve)	128.31	102.12	7.1 kg			Replace
4	Oil cooler by-pass valve spring	75.0	72.0	6.0 kg			
5	Main relief valve operating pressure	Standard: 3.3 ± 0.3 kg/cm^2					
6	Regulator valve operating pressure	Standard: 8.0 ± 0.8 kg/cm^2					Repair or replace spring
7	Piston cooling valve operating pressure	Standard: $1.3^{+0.3}_{-0.1}$ kg/cm^2					
8	Oil cooler by-pass vavle operating pressure	Standard: 4.5 ± 0.5 kg/cm^2					

WATER PUMP



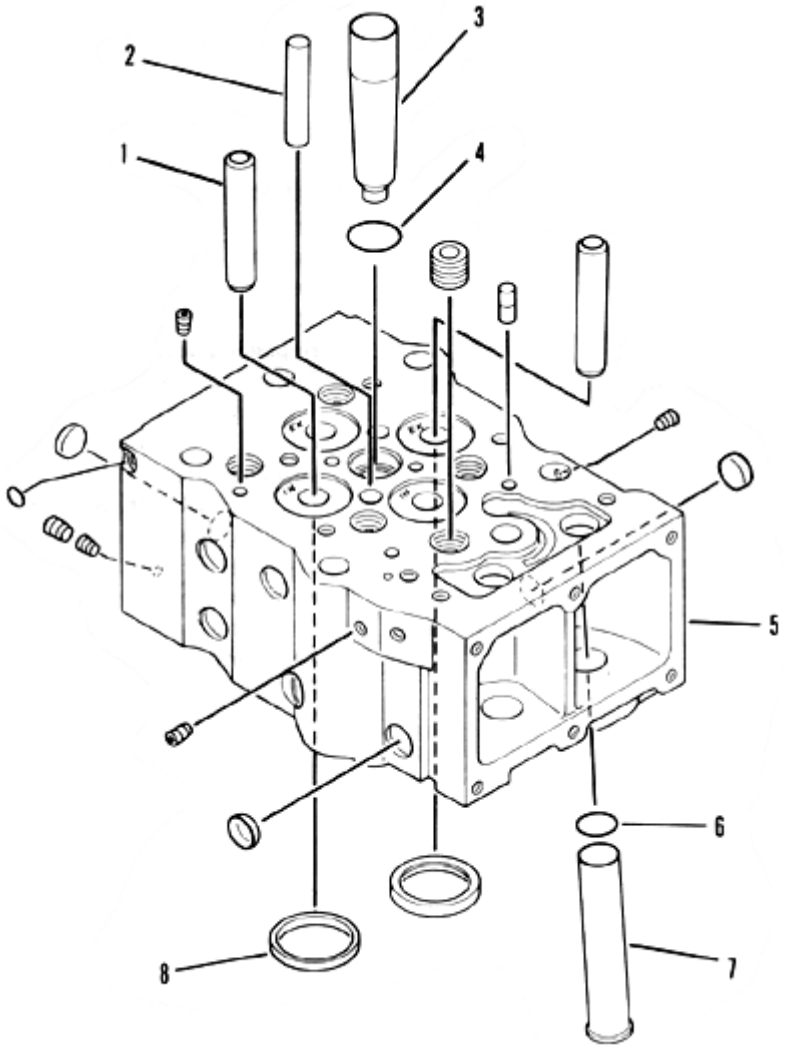
unit: mm

No.	Check item	Criteria				Remedy
1	Interference between front shaft and bearing	Standard size Shaft 30	Tolerance Hole +0.015 0	 interference 0 -0.010	Standard 0 to 0.025	Replace
2	Interference between rear shaft and bearing	25	+0.010 0	0 -0.010	0 to 0.020	
3	Interference between rear shaft and ompeller	19.9	+0.020 +0.005	-0.025 -0.05	0.030 to 0.070	
4	Clearance between impe-ller and connection	Standard clearance 0.23 to 0.66		Clearance limit -		

ENGINE

16 REPAIR AND REPLACEMENT OF PARTS

CYLINDER HEAD

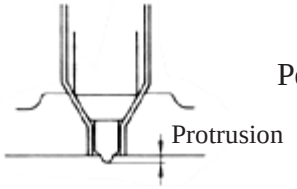
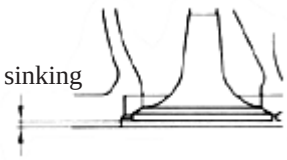
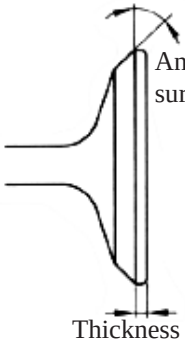


1. Valve guide
2. Cross head guide
3. Fuel injection nozzle sleeve
4. O-ring
5. Cylinder head
6. O-ring
7. Pushrod tube
8. Valve sea insert

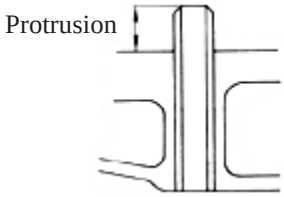
TESTING AND INSPECTING

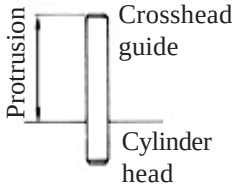
(1) Cylinder head

Unit : mm

Inspection item	Judgement standards	Remedy
A. Cracks, leakage from cylinder head	. Check for cracks (external color check) . Check for air leakage with air pressure test (3.0 - 3.5 kg/cm², 30sec.) . Water pressure test (3.5 - 4.0 kg/cm², 10 min.)	Repair by welding or replace
B. Distortion of top bottom surface of cylinder head	Tolerance: Max. 0.05 / Repair limit: 0.1	Grind to correct
C. Damage to injection nozzle sleeve seat surface, contact width		Machine to repair or replace sleeve
D. Protrusion of injection nozzle	 Permissible range: 4.9 - 5.7	Replace sleeve
E. Damage to valve seat surface or loosening of seat	. Pitting of seat surface . Check contact between valve and seat surface . Airtighteness test . Tap cylinder head and check for looseness	Correct seat surface or replace valve seat
F. Sinking of valve (both intake and exhaust)	 Standard value: 0.9 - 1.5 / Repair limit: 2.1	Replace valve or valve seat
G. Thickness of valve head	 . Thickness of valve head: Intake valve Standard value 3.4, Repair limit 2.9; Exhaust vavle Standard value 3.5, Repair limit 3.1 . Angle of seat surface: Intake valve : 30°, Exhaust valve : 45°	Replace

Unit : mm

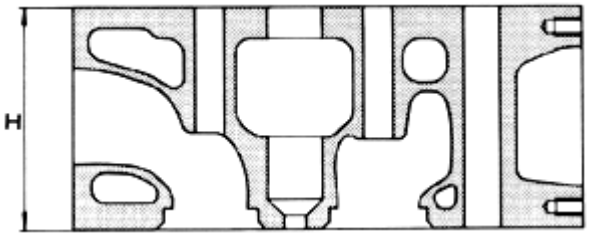
<table>
<tr><th>Inspection item</th><th>Judgement standards</th><th>Remedy</th></tr>
<tr><td rowspan="2">H. Abnormality in valve</td><td>. Check if head has becomes flat, check or pitting of seat surface
. Airtightness test
. Check for play in cotter pin when new cotter pin is inserted in cotter groove</td><td>Replace</td></tr>
<tr><td>. Check for eccentric wear or curvature of stem.</td><td>Correct</td></tr>
<tr><td>I. Outside diameter of vavle stem</td><td>. Outside diameter
<table><tr><th>Standard size</th><th>Standard value</th><th>Repair limit</th></tr><tr><td>12</td><td>11.908 - 11.893</td><td>11.80</td></tr></table></td><td>Replace</td></tr>
<tr><td>J. Inside diameter of vavle guide</td><td><table><tr><th>Standard size</th><th>Standard value</th><th>Repair limit</th></tr><tr><td>12</td><td>11.981 - 11.999</td><td>12.10</td></tr></table></td><td rowspan="3">Replace</td></tr>
<tr><td>K. Protrution of valve guide</td><td> 

Permissible renge : 23.4 - 23.9</td></tr>
<tr><td>L. Outside diameter of crosshead guide</td><td><table><tr><th>Standard size</th><th>Standard value</th><th>Repair limit</th></tr><tr><td>15</td><td>15.028 - 15.039</td><td>15.00</td></tr></table></td></tr>
<tr><td>M. Protrusion of crosshead guide</td><td> 

Pemissible range : 53.7 - 54.0</td><td>Correct</td></tr>
</table>

REPAIRING MOUNTING FACE OF CYLINDER HEAD BY GRINDER

Grinding



1) Remove the valve seat inserts. For details, see REPLACING VALVE SEAT INSERTS.
2) Remove the nozzle holder sleeves. For details, see REPLACING NOZZLE HOLDER SLEEVS.
3) Grind the cylinder head to remove the strained or corroded portion within the limit of the height of the cylinder head (H).

   - ★ **Repair limit of cylinder head height (H): 139.55 mm**
   - ★ **Amount to remove per grinding: 0.10 to 0.1 mm**
   - ★ **Surface roughness of grinding surface: within 6S**
   - ★ **Flatness (deformation): 0.05 mm max.**
   - ★ **Grinding limit: 0.3 mm**
   - ★ **Difference in head height per unit: 0.15 max.**

4) Press-fit the one-size-larger inserts. For details, see REPLACING VALVE SEAT INSERTS.
5) Press-fit the nozzle holder sleeves. For details, see REPLACING NOZZLE HOLDER SLEEVES.

Check after grinding

Check the sinking of the valves and the protrusion of the nozzles are within the standard valves.

- ★ **Standard sinking of valves : 0.9 to 1.5 mm**
- ★ **Allowable protrusion of nozzle : 4.9 to 5.7 mm**

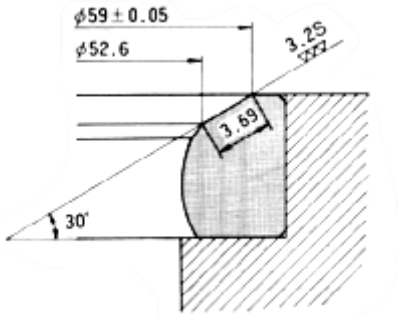
REPLACING VALVE SEAT INSERTS

Special tools required

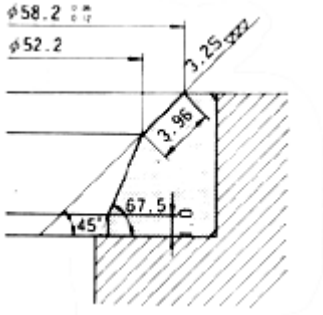
Symbol	Part No.	PartName	Qty.
A	795-100-4800	Valve seat puller	1
B	795-100-3002	Valve seat cutter	1
C	795-600-2510	Push tool (for intake valve)	1
C	795-600-2520	Push tool (for exhaust valve)	1
D	795-600-2530	Calking tool (for exhaust valve)	1
D	795-600-2540	Calking tool (for exhaust valve)	1
D	795-602-2510	Body	1

When repairing the cylinder head without removing the valve seat inserts, see the following figures.

- Intake valve



- Intake valve



1. Pulling out the valve seat insert

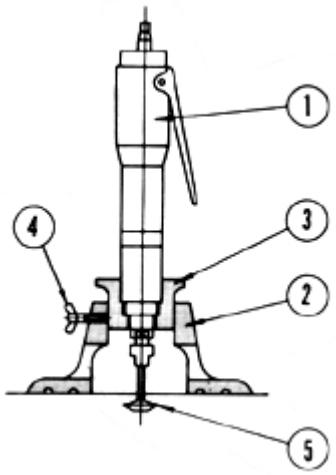
1) Using the grinder of valve seat puller A, make grooves on the inserts to pull them out according to the following procedure.
   - ★ Set the air pressure to 5 to 6 kg/cm^2.
   - ★ When replacing the grindstone of the grinder, shut off the compressed air.

⚠ Before using the grinder, run it for a minute to set test it.
- After replacing the grindstone, run the grinder for three minutes to test it.

⚠ Confirm that the grindstone is not damaged, then install it to the shaft of the grinder without applying excessive force.
Confirm that there is no play between the grindstone and shaft.

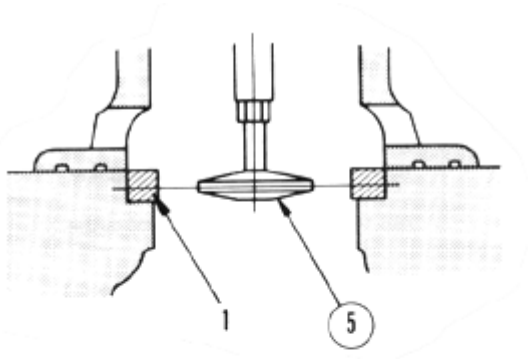
⚠ When using the grinder, wear safety goggles.

i) Install grindstone ⑤ to grinder ①.
ii) Install the sleeve and grinder after aligning the groove of sleeve ③ with holder ② . Adjust th position of the grinder with set screw ④.

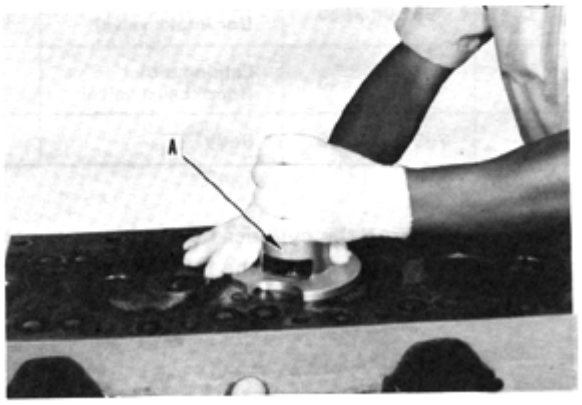


iii) Adjust the position of the grinder so that the center of grindstone ⑤ will be at the center of seat insert (1), then tighten the set screw to secure the grinder.

iv) Fully open the throttle of the grinder to rotate the grinderstone and slowly move it until it contacts insert (1).



v) Press the grindstone against the inside of the insert, move it in a circuar pattern, and make a groove about 1 mm deep.



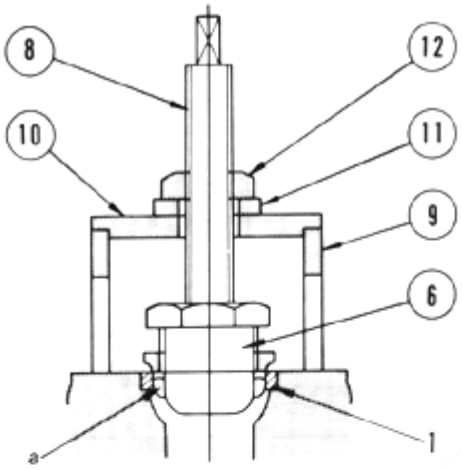
2) Pull out the insert with the puller head of valve seat puller **A** according to the following procedure.

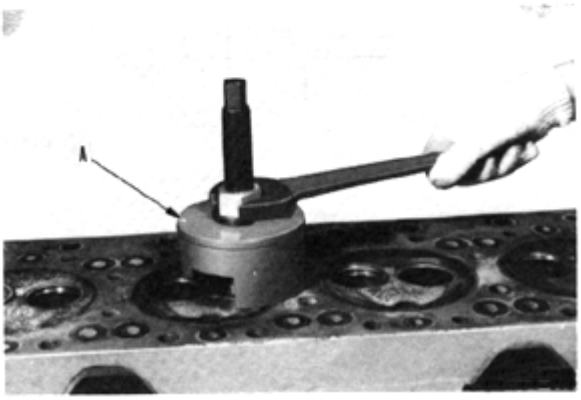
i) Push three claws (a) of puller head ⑥ inward by hand and put them in insert(1).

ii) Tighten screw ⑧ to press the three claws against the groove on the inside surface of the insert.

★ If the screw is tigtened too strongly, the insert will break and it will be difficult to pull itout. Therefore, stop tightening the screw when the claws completely contact the groove.

iii) Place birdge ⑨ over the puller head, then place plates ⑩ and ⑪ on the bridge. Tighte nut ⑫ to pull out the insert.

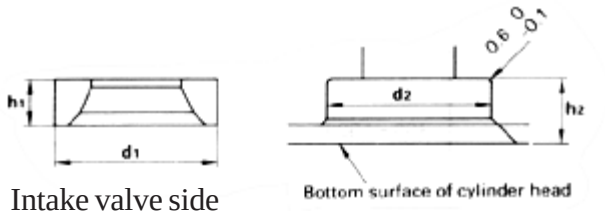




2. Machining valve seat insert mounting hole to oversize

1) Using valve seat cutter B, machine the mounting hole to install a one-size-lager insert.

- Dimensions of insert and monting hole



- Intake valve side

Unit: mm

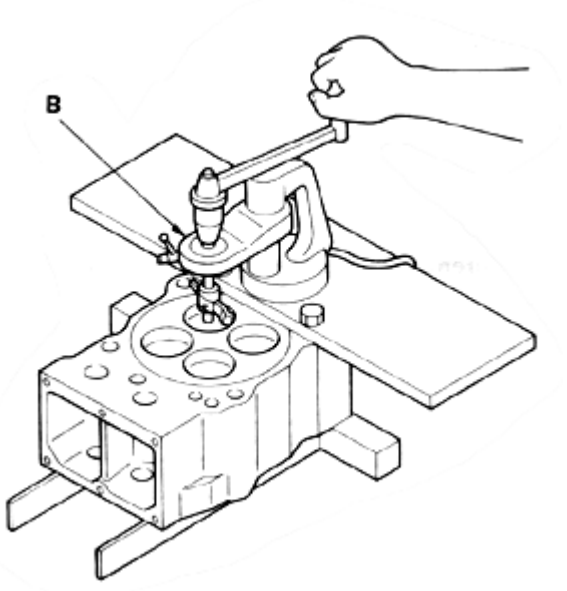
Stamp on insert	insert		Mounting hole for insert	
	O.D. (d_1)	Hight(h_1)	I.D. (d_2)	Depth(h_2)
S.T.D.	63.00 $^{+0.100}_{+0.080}$	8.5 $^{0}_{-0.1}$	63.00 $^{+0.020}_{-0.010}$	12.5 ± 0.1
0.25 O.S	63.25 $^{+0.100}_{+0.080}$	8.5 $^{0}_{-0.1}$	63.25 $^{+0.020}_{-0.010}$	12.5 ± 0.1
0.50 O.S	63.50 $^{+0.100}_{+0.080}$	8.62 $^{0}_{-0.1}$	63.50 $^{+0.020}_{-0.010}$	12.62 ± 0.1
0.75 O.S	63.75 $^{+0.100}_{+0.080}$	8.75 $^{0}_{-0.1}$	63.75 $^{+0.020}_{-0.010}$	12.75 ± 0.1
1.00 O.S	64.00 $^{+0.100}_{+0.080}$	8.88 $^{0}_{-0.1}$	64.00 $^{+0.020}_{-0.010}$	12.88 ± 0.1

- Exhaust valve side

Unit: mm

Stamp on insert	insert		Mounting hole for insert	
	O.D. (d_1)	Hight(h_1)	I.D. (d_2)	Depth(h_2)
S.T.D.	61.00 $^{+0.100}_{+0.080}$	8.5 $^{0}_{-0.1}$	61.00 $^{+0.020}_{-0.010}$	12.5 ± 0.1
0.25 O.S	61.25 $^{+0.100}_{+0.080}$	8.5 $^{0}_{-0.1}$	61.25 $^{+0.020}_{-0.010}$	12.5 ± 0.1
0.50 O.S	61.50 $^{+0.100}_{+0.080}$	8.62 $^{0}_{-0.1}$	61.50 $^{+0.020}_{-0.010}$	12.62 ± 0.1
0.75 O.S	61.75 $^{+0.100}_{+0.080}$	8.75 $^{0}_{-0.1}$	61.75 $^{+0.020}_{-0.010}$	12.75 ± 0.1
1.00 O.S	62.00 $^{+0.100}_{+0.080}$	8.88 $^{0}_{-0.1}$	62.00 $^{+0.020}_{-0.010}$	12.88 ± 0.1

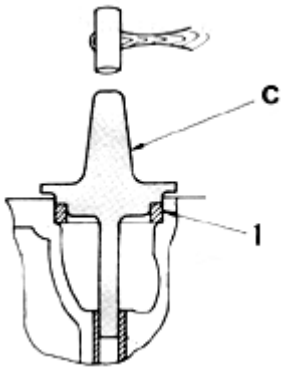
★ Inside surface roughness: 12.5S max.
★ Mounting hole bottom roughness: 12.5S max.
★ Concentricity of inside diameter of valve guide and inside diameter of insert hole: 0.05 mm (T.I.R) max.
★ Rectangularity of inside diameter of valve guide and bottom of insert hole :
:0.03 mm (T.I.R) max.



2) If the calked portion of the mounting hole, is damaged remove it within the range of 1.00mm oversize. If the damage portion cannot be removed within the range of 1.00 mm oversize, replace the cylinder head.

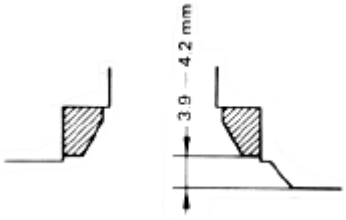
3. Press fitting the insert

1) Using insert push tool **C,** Press-fit the insert (1) .



2) Check the sinking distance of the insert from the mounting, surface of the cylinder head.

★ **Standard sinking distance of insert:**
3.9 to4.2 mm.



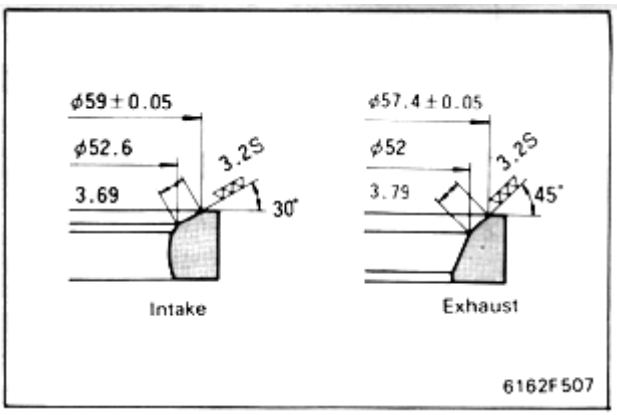
4. Finishing seat surface

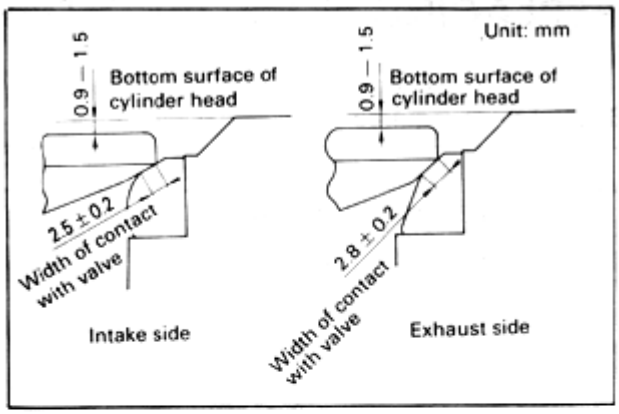
1) Using valve seat cutter B, finish the seat surface to the dimensions shown in the diagram.
   - ★ Seat surface angle Intake : 30°
     Exhaust : 45°
   - ★ Seat finishing width Intake : 3.69 mm
     Exhaust : 3.79 mm
   - ★ Concentricity of valve guide and insert
     Within 0.07 mm (T.I.R.)
2) Rub the seat surface with compound.
   - ★ Standard sinking of valve (new part) :
     0.9 - 1.5 mm
   - ★ Checking width of contact with valve
     New part (reference value)
     Intake : 2.5 ± 0.2 mm
     Exhaust : 2.8 ± 0.2 mm

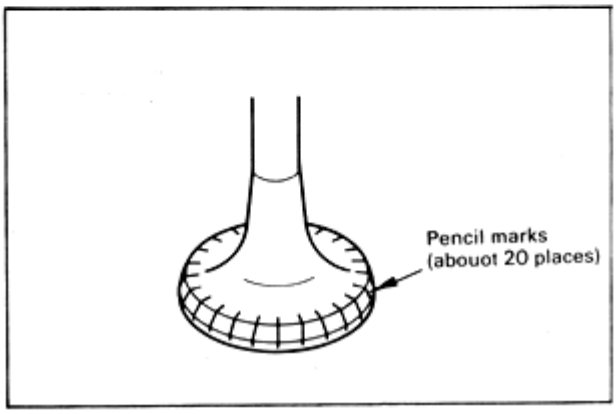
Final inspection

- Coat the seat surface of the new valve thinly with red lead (minimum), insert it inthe valve guide, push lightly against the valve insert surface, and rotate 10°. Check the valve insert contact surface, and confirm that the contact is uniform without any breaks.
- Another way is to make marks with a pencil on the seat surface of the new valve as shown in the diagram below, insert it in the valve guide, push lightly against the valve insert surface, and rotate10°. Check that the pencil marks have been erased uniformly around the whole circumference.
- When carrying out an airtighteness test wih a vacuum tester, test as follows.

1) Wipe off all the dirt, dust and oil from the valve and valve seat surface with a cloth.
2) Assemble the cylinder head as specified, then tap the tip of the valve stem with a plastic hammer 2 or 3 times directly fom above to bring it into tight contact with the seat surface.
3) Fit a vacuum cup that matches the size of the valve in tight contact with the head surface. When doing this, to improve the airtightness of the vacuum cup, coat grease on the O-ring fitted to the vacum cup, and fit it in tight contact with the flat surface of the head.
   - ★ Be careful not to get any grease on the seat surface.
4) Set the vacum gauge, and check that the pressure drops less than 10 mmHg in 3 seconds. If it drops more than 10 mmHg in 3 seconds, check for any dirt on the seat surface, or rub the surface to correct it.



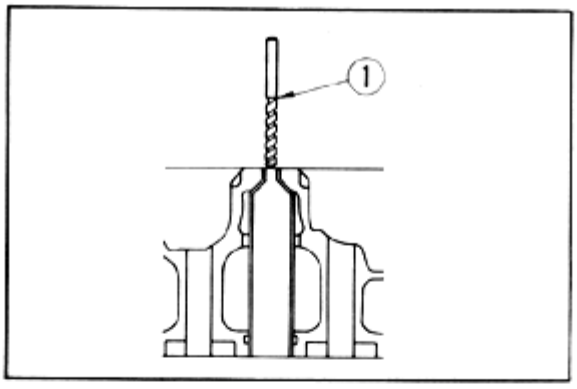




REPLACEING NOZZLE HOLDER SLEEVE

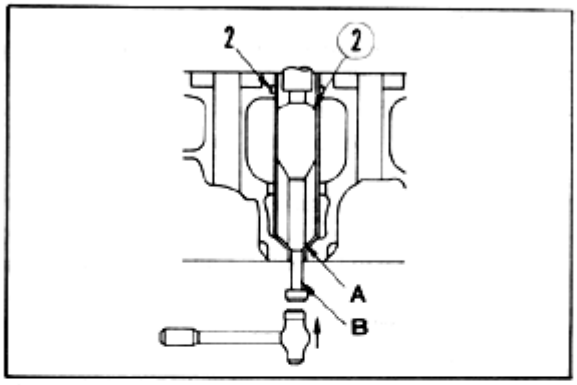
Special tools required

No.	Part No.	Part Name	Qty.
A	795-600-2110	Push bar	1
B	795-600-1191	Push bar	1
C	795-600-2120	Sleeve driver	1
G	795-600-2140	Sleeve expander	1
H	795-600-2150	Sleeve expander	1
I	795-600-2160	Sleeve cutter	1
J	795-600-2170	Guide bushing	1
K	795-600-1151	Sleeve expander	1



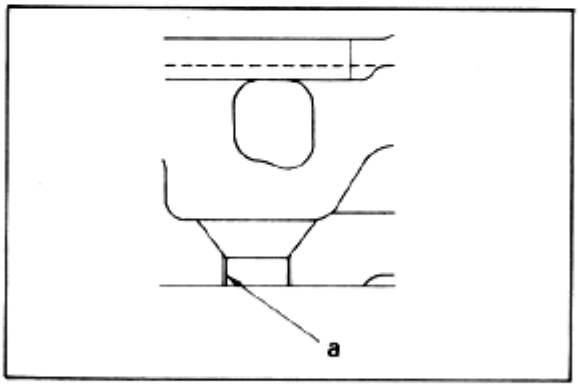
1. Cutting hoel at bottom of sleeve

- Insert drill (ø12 mm) ① into the hole at the bottom of the sleeve, and drill the hole diameter.



2. Removing sleeve

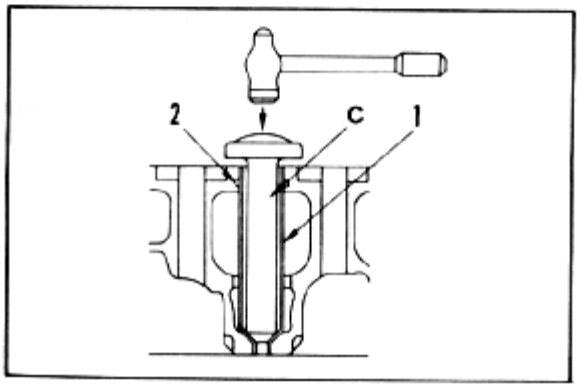
1) Insert push bar **A** inside the sleeve.
2) Apply oil and use sleeve removal tap ② to make a tap to approx. 25 mm from the end face at the top of the sleeve.
   - ★ Removal tap: M32, P=2.0
3) Insert push bar B from the bottom surface of the head, and tap with a hammer to remove the sleeve.
4) Remove all the remaining sleeve material stuck in the tap of portion.
5) Remove O-ring (2).



3. Press fitting sleeve

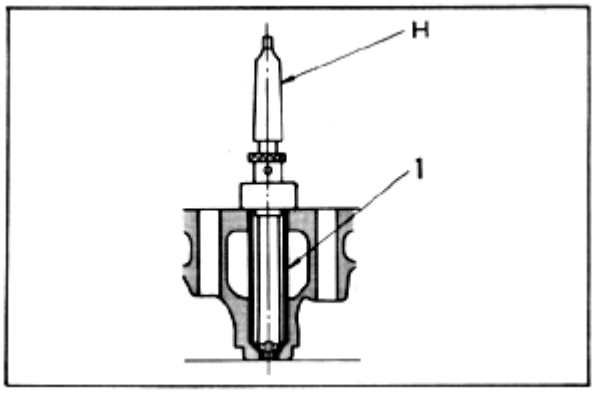
1) Insert O-ring (2) in the O-ring groove.
2) Insert sleeve (1) in the cylinder head, then use sleeve driver **C** and tap in until the sleeve
   - ★ Clean the sleeve and seat completely.
   - ★ Coat the seat portion on the otside circumference of the sleeve with adhesive.

Adhesive: LT-2



4. Rolling sleeve taper portion

- Using sleeve expande **H**, roll the sleeve taper portion.
  - ★ Install sleeve expander **H** to a radial drilling machine or upright drilling machine, push the roller portion at the top strongly against the sleeve taper portion, and roll for approx. 20-25 sec. Check that the rolling surface is being rolled, and repeat the operation 2 - 3 times.
  - ★ Rotating speed : 200 - 300 rmp



5 Compressing hole at bottom of sleeve

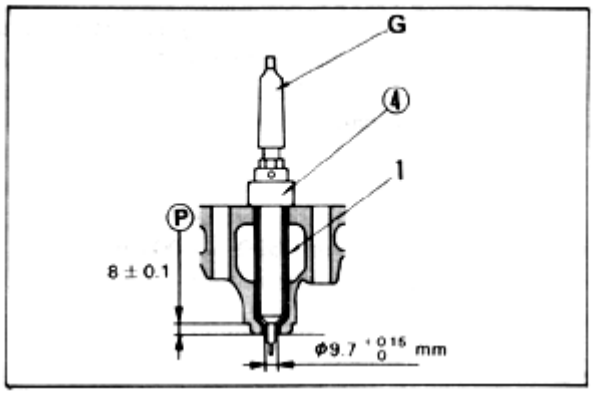
Using sleeve expander **G**, roll the hole (portion Ⓟ) at the bottom of sleeve (1).

- ★ With the shank of sleeve expander **G** pulled up and the roller portion at the tip coming out slightly from the bottom hole, adjust the mounting position with bearing collar④of the tool.
- ★ Install sleeve expander **G** to a redial drilling machine or upright drilling machine, push in a a little at a time, and roll to the standard dimension.

Note: Install sleeve sxpander **G** to the drilling machie with the shank pulled up.

- ★ Rotating speed : 200 - 300 rmp
- ★ Diameter of bottom hole after rolling :

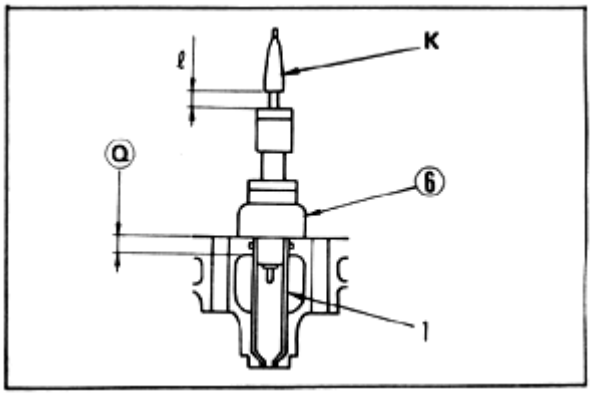
$$\varnothing 9.7\ ^{+0.015}_{0}\ \text{mm}$$



6 Repeat the procedure in Stop 4 and roll the sleeve taper portion again.

7. Rolling hole at top of sleeve

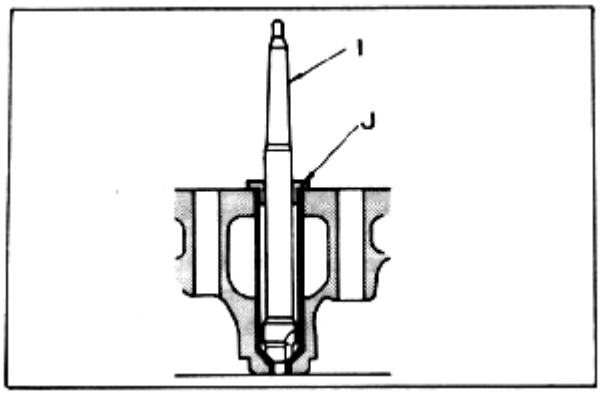
- Using sleeve expander **K**, roll the (portion **Q**) at the top of sleeve (1).
  - ★ With the shank of sleeve expander **K** pulled up, push in the roller portion at the tip to a depth where the whole of portionⓆcan be rolled, and adjust the mounting position with bearing collar⑥of the tool.



★ Allow the shank to sink under its own weight, and note the position (measure dimension ℓ).
★ Install sleeve expander **K** to a radial drilling machine or upight drilling machine, and after allowing the shank to sink under its own weight, push it lightly and carry out rolling to a position 4 - 6 mm lower.
Note: Install sleeve expander **K** to the drilling machine with the shank pulled up.
★ Rotating Speed : 100 - 200 rpm

8. Spot facing seat portion inside sleeve

1) Using guide bushing **J** as a guide, carry out spot facing of the seat portion with sleeve cutter **I**.
★ When cutting the seat surface, use a holder and dial gauge to measure the protrusio of the nozzle, cut and check a little at a time so that the protrusion of the nozzle comes within the standard value.
★ Rotating speed : 500 - 600 rpm
★ Protrusion of nozzle : 4.9 - 5.7 mm



2) Remove all dirt and metal particles from the finished surface.

9 Checking for leakage from seat surface

- Carry out an air pressure test (or wate pressure test) to check for leakage from the sleeve seat surface.
- When using the air pressre test, apply air pressure (4 ± 0.3 kg/cm^2) for 30 seconds. There must be no leakage.
★ When checking for leakage from the seat surface, install a used nozzle holder.

Water pressure testing method

- If the area around the head has been corrected, test as follows.

Special tools required

Symbol	Part No.	Part Name	Qty.
A	790-553-1700	Coolant tester kit	1
B	79A-471-1050	Pump assy.	1

1. Checking for leakage from seat surface

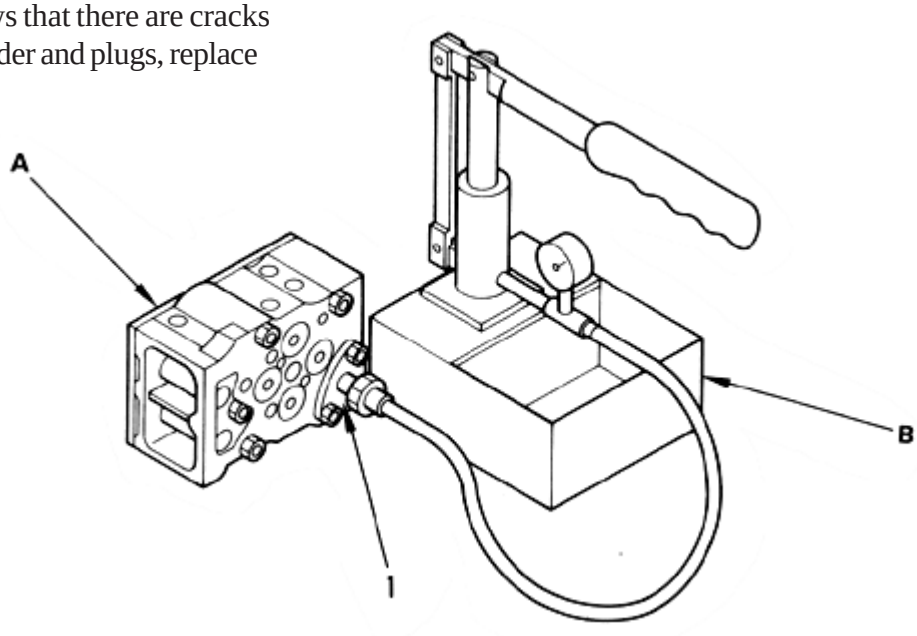
1) Tighten the nozzle holder assembly to the specified torque.
2) Assemble tool **A** and tool **B**, and connect a hose to flange (1).
3) Apply water pressure (3.5 - 4.0 kg/cm^2) for appox. 10 minutes, and check for any leakage from around the head.

★ It is preferable to warm the whole cylinder head and carry out the test with hot water (82 - 93° C).

2. Air pressure test

1) Tighten the nozzle holder assembly to the specified torque.
2) Connect the pump hose to flange (1).
3) Place the head in a water bath, appl air pressre (3.0 - 3.5 kg/cm^2) for approx. 30 seconds, and check for any air leakage in the water.

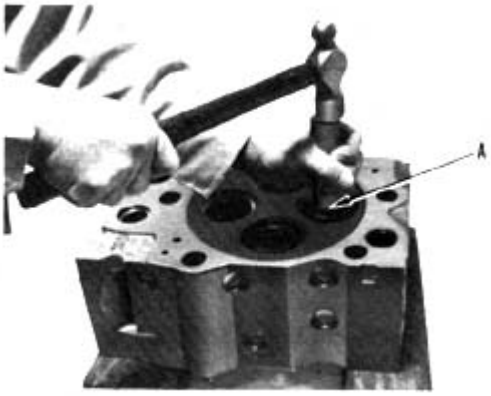
★ It the above test shows that there are cracks around the nozzle holder and plugs, replace the cylinder head.



REPLACING VALVE GUIDE

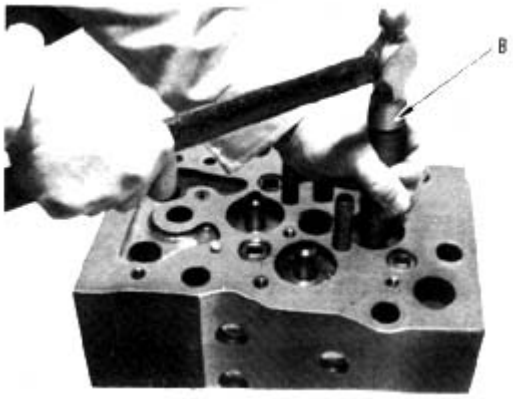
Special tools required

Symbol	Part No.	Part Name	Qty.
A	795-600-2550	Valve guide remover	1
B	795-600-2560	Valve guide driver	1



1. Removing the valve guide

- Remove the guide with valve guide remover **A.**



2. Press-fitting the valve guide

1) Press-fit the valve guide until the tip of valve guide driver **B** contacts the cylinder head.
2) Confirm that the protrusion of the valve guide is within specification.
   - ★ **Protrusion of valve guide: $23.7^{+0.2}_{-0.3}$ mm**
   - ★ **Cylinder head valve guide inside diameter: $19^{+0.021}_{0}$ mm**

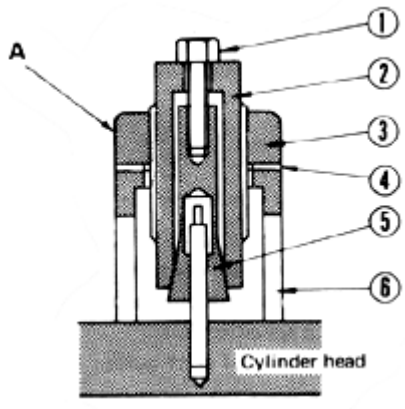
REPLACING CROSS HEAD GUIDE

Special tools required

Symbol	Part No.	Part Name	Qty.
A	795-140-6410	Cross head guide puller	1

1. Removing the cross head guide

- Using cross head guide puller **A,** pull out the cross head guide.
  1) As shown in the figure, hold the cross head guide with collet ⑤ of the puller.
  2) Tighten the collet with bolt ① to lock sleeve ②
  3) Rotate nut ③ and pull out the cross head guide.
  4) Remove burrs, fins, etc. from the mounting place of the cross head guide and clean it.



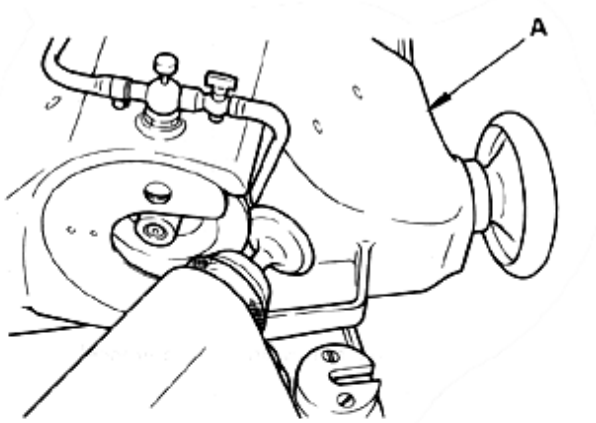
2. Press-fitting the cross head guide

- Insert the cross head guide in the cylinder head, then hit it into the cylinder head with a copper bar or plastic hammer until its protrusion is within specification.
  - ★ **Protrusion of cross head guide**
    Tolerance: $54\ ^{0}_{-0.3}$ mm
  - ★ **Inside diameter of crosshead guide hole: $15\ ^{+0.018}_{0}$ mm**

GRINDING THE VALVE

Special tools required

Symbol	Part No.	Part Name	Qty.
A	- (Purchase)	Valve refacer	1

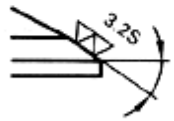


1. Grinding the seat surface

- Grind the seat surface with valve refacer A.
  - ★ **Angle of valve seat :**
    Intake valve : 30°
    Exhaust valve : 45°

2. Checking after grinding

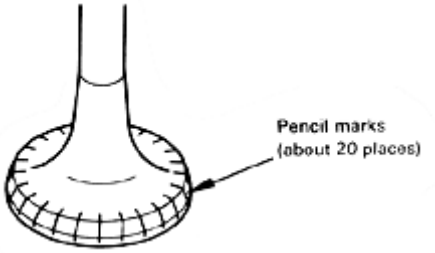
- Confirm that the thickness of the valve head, protrusion of the valve, and the contact surface of the valve seat are within specification.
- ★ Thickness of valve head
  Repair limit
  Intake valve : Min. 2.9 mm
  (Standard size 3.4 mm)
  Exhaust valve : Min. 3.1 mm
  (Standard size 3.5 mm)



- ★ Sinking of valve Standard : 0.9 - 1.5 mm
  Repair limit : 2.1 mm

- ★ Check the contact of the valve with the seat surface using one of the following methods.
  - Coat the seat surface of the ground valve thinly with red lead (minimum), insert it in the valve guide, push lightly against the valve insert surface, and confirm that the contact is uniform without any breaks.

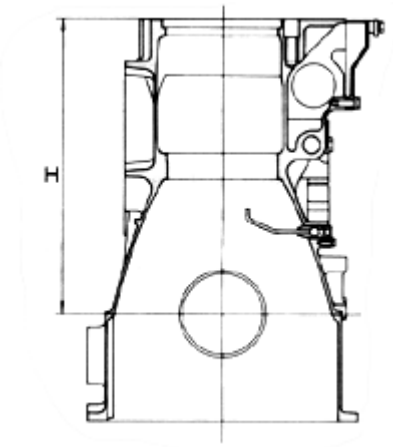
  - Make marks with a pencil on the seat surface of the ground valve a sshown in the diagram, insert it in the valve guide, push lightly against the valve insert surface, and rotate 10°. check that the pencil marks have been erased uniformly around the whole circumference.



GRINDING THE TOP SURFACE OF CYLINDER BLOCK

1. Grinding

- Grind off the strained and corroded portions of the cylinder block within the allowable height (H) of the cylinder block.
  - ★ **Allowable height (H) of cylinder block: 509.84 mm**
  - ★ **Grinding depth/time: 0.03 to 0.08 mm**
  - ★ **Roughness of ground surface: 6.3S max.**
  - ★ **Flatness (deformation): 0.09 mm max.**



If grinding with a grindstone(for reference)

- ★ **Speed of grindstone: 1,650 to 1,90m/min.**
- ★ **Speed of table: 15 to 30 m/min.**
- ★ **Grinding depth/time: 0.025 mm**
- ★ **Cross feed/time: 1 to 2 mm**
- ★ **Grindstone: A46IV**
- ★ **Grinding lubricant: Water-soluble grinding lubricant**

2. Checking after grinding

- Check the protrusion of the cylinder liner. If it is out of specification, repair the counterbore. For details, see REPAIRING THE COUNTERBORE.
  - ★ **Protrusion of cylinder liner**
    Allowable range: 0.07 to 0.15 mm
    Difference among cylinders: 0.05 mm max.

REPLACING MAIN METAL CAP

★ When replacing the main metal cap, machine the semi-finished part according to the following procedre.

1. Machining the bore of main metal cap

1) Remove the cylinder liner.
2) Install the replacement metal cap to the cylinder block and tighten it to specification.

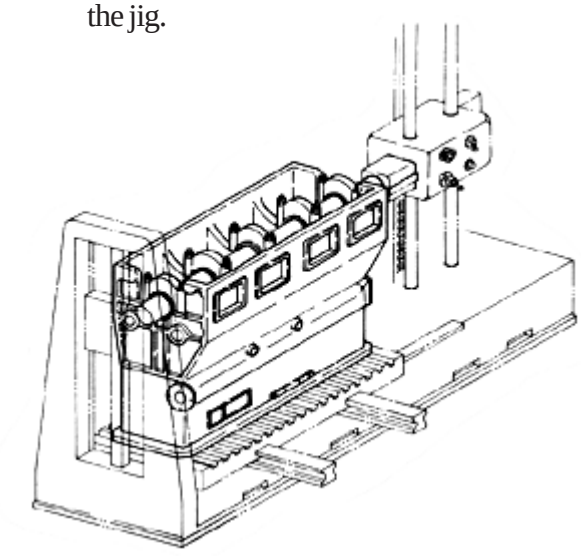
kgm Mounting bolt for main metal cap:

Unit: kgm

Step	Target	Range
1st	56	51 - 61
2nd	113	107 - 118
3rd	0	Completely loosen
4th	38	33 - 43
5th	75	70 - 80
6th	113	07 - 118

★ Align the notches on the cylinder block and cap.

3) Set the jig for mounting the cylinder the cylinder block to the table of a horizontal boring machine. Install the cylinder block by mounting its hole for the liner to the datum plug of the jig.



4) Center the arbor of the boring machine by applying a dial gauge to the inside wall of the two metal caps which have the largest pitch in the metal caps to be used again.

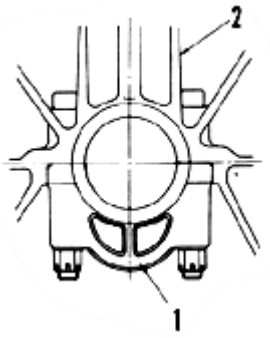
5) Cut the inside of metal cap (1) little by little while checking its inside diameter.

★ Cut until the cutting tool contacts the inside wall of cylinder block (2).

★ **Inside diameter of main cap: $148^{+0.025}_{0}$ mm**

★ **Surface roughness: 3.3S max.**

★ Never cut the inside wall of the cylider block.



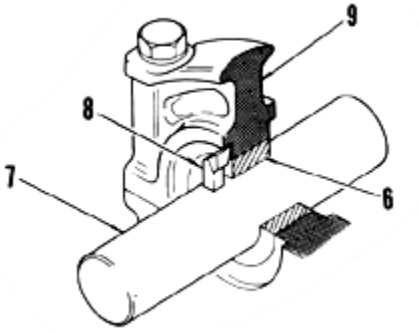
2. Correcting the width of the main metal cap

1) Insert cast iron bushing (6), and pass arbor (7) through.
2) Install facing tool (8) to the arbor.
3) Cut cap (9) until the cutting tool contacts the cylinder block.
4) Cut the opposite side in the same way.

★ **Width of main cap: $56^{0}_{-0.030}$ mm**

★ **Roughness of surface facing thrust metal: 12.5S max.**

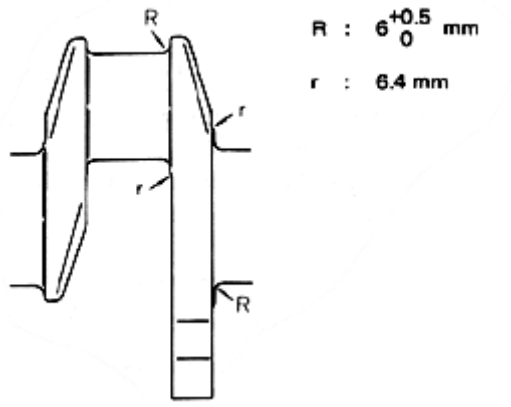
★ Never cut the cylinder block.



REPAIRING THE CRANKSHAFT

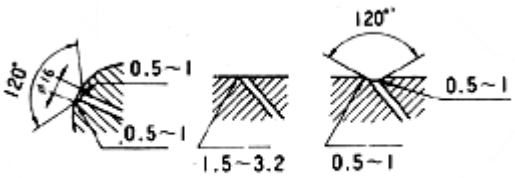
- If the crankshaft is worn or slightly seized or damaged, cut it to any one of the following thicknesses.
  Undersize dimensions : 0.25, 0.50, 0.75, 1.00 mm
- If the crankshaft is bent or worn unevenly, replace it instead of repairing it. (A lot of skill is required to repair it.)
- Only the following sections can be repaired by plating.
  1. Rear seal journal
  2. Section to which crank gear is installed

- Carefully finish section **R** of the fillet of the crankshaft, section **r** on the shoulder, and section **R** facing the hole.
- Dimension of fillet



- Dimension of oil hole on journal

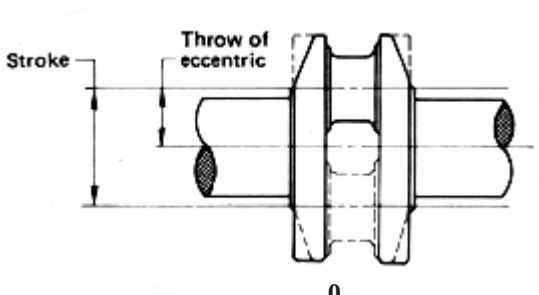
Main journal Pin journal



The width of the connecting section of the oil holes must be at least 2.0, and the surface roughness must be 1.6S at maximum. Other surface of the round section must be finished within 6S.

★ **Tolls and jigs required for cutting**
1) Magnetic flaw detector
2) Shore hardness tester
3) Etching kit
4) Crankshaft cutting machne
5) Crankshaft grinding machine
6) Roughness gauge
7) Ball gauge for measuring radii of fillets
   For minimum value : 795-500-1140
   For maximum value: 795-500-1150

1. Check before cutting
1) Visual check
   Check for cracks, damage, seizure, discoloration, wear,etc. to see if it can be repaired.
2) Hardness test of journal
   Hardness of journal (Shore hardness)
   Allowable range : 60 to 67 Hs
   Limit : 60 Hs
   If the hardness is below the limit, dispose of the crankshaft.
3) Torsion test



Throw of eccentric: $85^{0}_{-0.15}$ mm

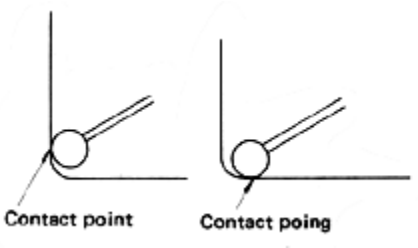
Limit of horizontal displacement (Difference in throw of eccentric between No. 1 cylinder and the rearmost cylinder): **0.94 mm**

Dispersion of throws of eccentric among cylinders : 0.20 max.

If the above values are out of specification dispose of the crankshaft.

2. Check during and after cutting

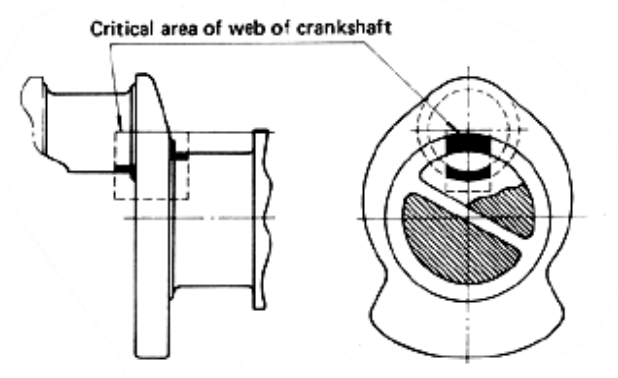
1) Checking the round sections of fillets
   i) Confirm that the round sections of fillets are smoothly connected to the shoulders of journals.
   ii) Using ball gauges for measuring the radii of the fillets, cofirm that each radii is between the minimum and maximum limits.



Minimum radius of fillet : 6.00 mm
Maximum radius of fillet : 6.50 mm

2) Checking the seized surfaces by etching
- After cutting the journals, confirm that no parts were seized in the cutting pocedure by the etching test.
- If any seized part is found, cut the journal another 0.02 mm to apply the next undersize.
- After etching the journals, neutralize and wash the checked surface, then apply oil.

3) Magnetic flaw detecting
- Before sin the repaired crankshaft, confirm that there are no cracks on it by magnetic flaw detection.
- Check the fillets of journals which are put in the critical area of each web of the crank shaft especially carefully.



4) Measuring the bend (Alignment)
- Measure the bend of the repaired crankshaft.
- Measure the bend (alignment) at the following four places.

i) Overall length alignment: 0.09mm max.
ii) Adjoining alignment: 0.05 mm max.
iii) Forward end alignment: 0.04mm max.
iv) Rear end alignment : 0.03 mm max.

3. Cutting the main journals

★ Cut all the main jornals to the same under size.
★ When cutting the main journals, count in the finishing allowance for grinding 0.007 to 0.008mm

- **Undersized of main journal**

Unit: mm

Size	Basic dimension	Allowable error
S.T.D	140.00	
0.25 US	139.75	0
0.50 US	139.50	-0.025
0.75 US	139.25	
1.00 US	139.00	

- **Out of roundness and cylindricality of main journals (T.I.R)**
  Limit : 0.015 mm
  Allowable error : 0.010 mm max.

4. Grinding the thrust bearing surface

- ★ It is not always required to grind the front and rear thrust bearing surfaces to the same undersize.
- ★ If the thrust bearing surfaces have been ground, confirm that the end play of the crankshaft is within the allowable range (For details, see DISASSEMBLY AND ASSEMBLY).

- **Undersizes of thrust bearing surfaces**

Unit: mm

			Rear thrust bearing surface	
			S.T.D	0.25 O.S
Front thrust bearing surface	S.T.D	Basic Dimension	$64^{+0.050}_{0}$	$64.25^{+0.050}_{0}$
		Limit	64.060	64.310
	0.25 O.S	Basic dimension	$64.25^{+0.050}_{0}$	$64.50^{+0.050}_{0}$
		Limit	64.310	64.560

Squareness of thrust bearing surface (T.I.R)

Limit: 0.04 mm

Allowable error: 0.035 mm max.

5. Grinding pin journals

- ★ Grind all the pin journals to the same undersize.
- ★ When grinding, count in finishing allowance for grinding 0.007 to 0.008 mm.

- **Undersizes of pin journal**

Unit: mm

Size	Basic dimension	Allowable error
S.T.D	108.00	
0.25 US	107.75	0
0.50 US	107.50	-0.020
0.75 US	107.25	
1.00 US	107.00	

- **Out of roundness and cylindricality of pin journal (T.I.R)**

Limit: 0.015 mm

Allowable error: 0.010 mm max.

6. Correcting the width of the main journal and pin journal by grinding

- When correcting the worn surfaces of the main journals ansd pin journals. limit the grinding thickness to the minimum.
- **Width of crank pin journal**

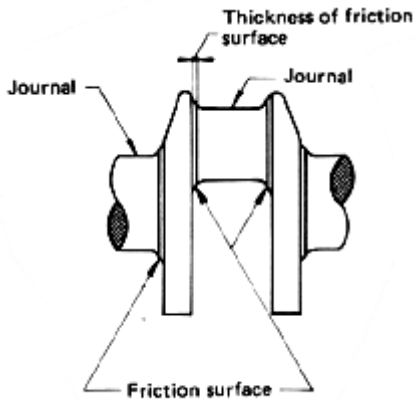
If cutting one side only:

Standard: $72^{+0.075}_{0}$ mm

Limit: 74.500 mm

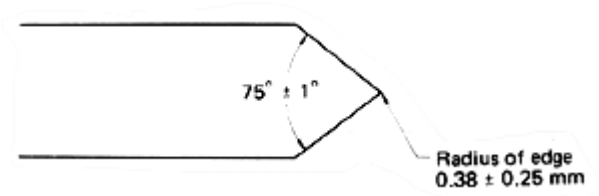
Squareness of thrust bearing surface (T.I.R)

Limit: 0.04 mm



7. Correcting the grindstone

- Dress the grindstone each time one journal is ground.
- Grindstone dressor
  Tip angl: 75° ± 1°
  Radius of edge: 0.38 ± 0.25 mm
  At the edges of the dresser, a diamond for industrial use must be embedded.



- Adjust the machine for correcting the grindstone, and correct the edge of the grindstone to the radius of the fillet.
- When checking and correcting the grindstone edge, grind a wood bar for trial and use ball gauges.

8. Preventing seizure caused by grinding

1) Use the plunge grinding method.
2) Use the overall width of the grindstone Do not grind the bosses if possible.
3) Apply sufficient cooling oil.
4) Set the circuferential speed of the grindstone to 2,000 m/min when the speed of crankshaft is 50 rpm.

9. Surface finishing

- Standard surface roughness
  Journal, thrust bearing, fillet: 1.6S max.
  Tapered end, boss of pin and main journal:3.2S max.
- Finishing allowance for grinding: 0.007 to 0.008 mm.

10. Treatment after grinding

- Confirm that each dimension is within specification.
- Carefully wash each section and apply oil to it.
- When storing the crankshaft for a long time, support it at three points or hang it vertically.

11. Balancing (for reference)

(Do not perform any repair which will have an adverse effect on the balance of the crankshaft).

- Limit of unbalance: 110 g.cm
- Limits of reading the balance correctly
  Bend of crankshaft: 0.05 mm (T.I.R)
  Speed of crankshaft: 325 rpm max.
- Balance the crankshaft with the crank gear installed or install a weight equivalent to the weight of the gear fixing key to the keyway.
- To balance the crankshaft, make a hole on the counter weight with a drill or cut it.
  Limit of amount of counterweight to be removed: 56 g.
  Number of holes: 5 max.
  Diameter of hole: 19mm max.
  Depth of hole: 50 mm max.
  Distance between hole and side face: 5 mm min.
  Distance among holes: 15° of central angle min.

REPLACING CAM BUSHING

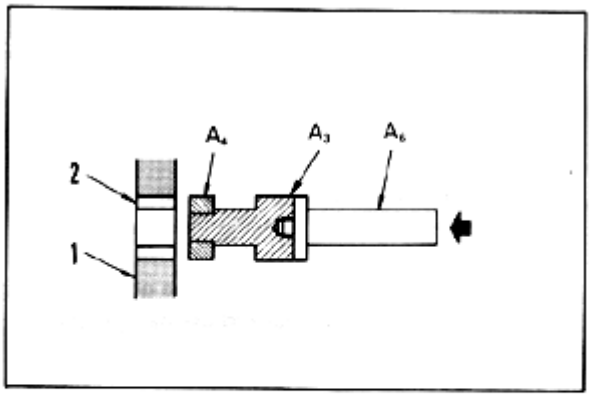
Special tools required

No.		Part No.	Part Name	Qty.
A		795-250-1301	Push tool	1
A	1	795-250-1310	Push bar	1
	2	795-250-1320	Push bar	1
	3	795-250-1330	Push tool	1
	4	795-250-1360	Collar	1
	5	795-250-1350	Guide	1
	6	792-103-0400	Grip	1

★ When replacing the cam bushing, first remove the blind plug at the rear of the cylinder block.

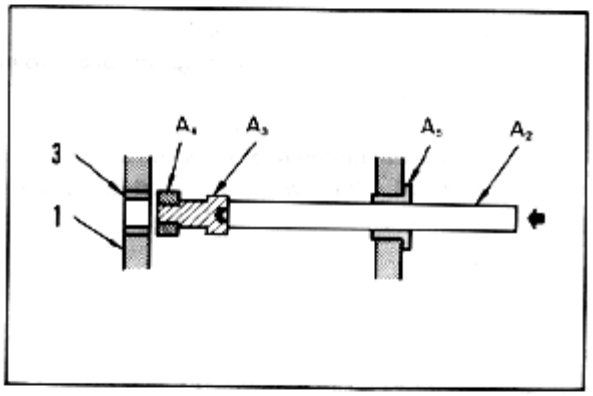
1. Removal of No. 1, 7 bushings

As shown in the diagram, assemble push tool **A3,** collar **A4,** and grip **A6,** then hit the push bar to knock bushing (2) out from cylinder block (1).



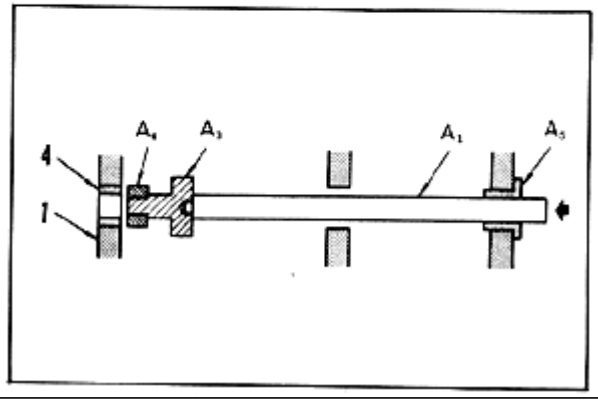
2. Removal of No. 2, 6 bushings

Assemble push bar **A2,** push tool **A3,** collar **A4,** and guide **A5,** then hit the push bar to knock bush ing (3) out from cylinder block (1).



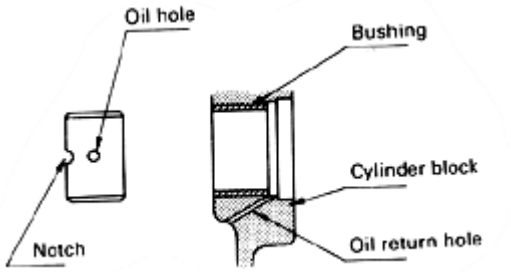
3. Removal of No. 3, 4, 5, bushings

Assemble push bar **A1,** push tool **A3,** collar **A4,** and guide **A5,** then hit the push bar to knock bushing (4) out from cylinder block (1).

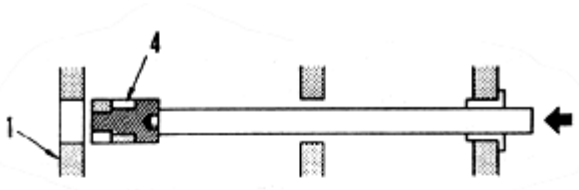


- After removing the bushing, remove any burrs or dirt, and clean the mounting hole of the bushing.

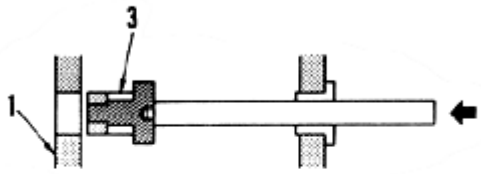
★ **Cam bushing assembly drawing**



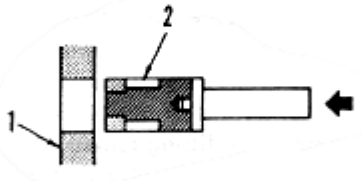
1. Press fitting No. 3, 4, 5 bushings
Assemble bushing (4) to tool **A**, and press fit the bushing until the oil hole of cylinder block (1) matches the oil hole of the bushing.



2. Press fitting No. 2, 6 bushing
Assemble bushing (3) to tool **A**, and press fit the bushing unit the oil hole of cylinder block (1) matches the oil hole of the bushing.

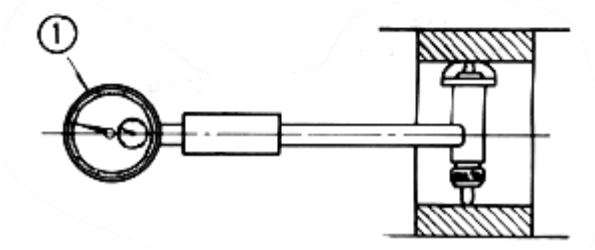


3. Press fitting No. 1, 7 bushings
Assemble bushing (2) to tool **A**, and press fit the bushing until the oil hole of cylinder block (1) matches the oil hole of the bushing.



- Using inside gauge ①, measure the inside diam eter of the bushing.
- Check the clearance between the bushing and shaft, and ifthe clearance is not within thespecified range, or the shaft does not move smoothly, correct the inside diameter of the bushing with reamer.
- When the inside diameter of the bushing has been corrected with a reamer, clean all the metal particles from the oil hole and oil groove.

★ Inside diameter cam bushing : see MAINTENANCE STANDARDS.



REPLACING CRANKSHAFT GEAR

Special tools required (or equivalent parts)

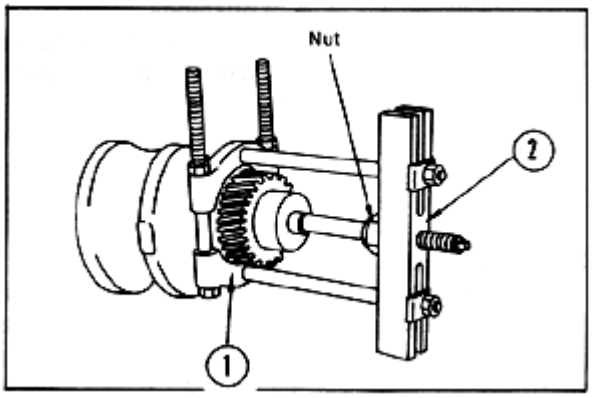
No.	Part No.	Part Name	Qty.
①	790-101-2800	Bearing puller	1
②	790-101-2300	Bearing puller	1

1. Removal of gear

Make a scratch in the surface at the root of the teeth with a grinder, then assemble pullers① and ② and turn the nut to remove the gear.

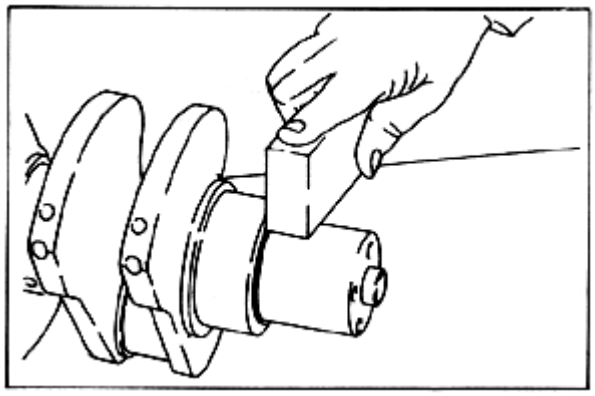
★ If the gear cannot be removed in this way, make a scratch in the surface at the root of the teeth with a grinder, then heat the gear with a burner and knock the gear out with a copper rod.

★ Be careful not to damage the shaft.



2. Press fitting gear

1) Check the gear mounting surface, key groove, and flange surface, and if there are any scratches, correct them with an oilstone.
2) Knock a new key into the key groove of the shaft.
3) Heat the gear for the specified time at the specified shink-fitting temperature.
   ★ Crankshaft gear shink-fitting temperature: 200° C
   Heating time: Min. 30 minutes
4) Put the timing mark on the outside, then use a hitting tool to press fit until the side face of the gear is in close contact with the shaft flange.
   ★ Knock in quickly before the gear becomes cool.



REPLACING CAM GEAR

1 Removal of gear

Set the camshaft assembly on the press stand, then push the camshaft to remove the gear.

⚠ When setting the camshaft assembly on the press stand, be careful not to get your fingers caught between the press stand and the gear.

2 Press fitting gear

1) Check the gear mounting surface, key groove, and flange surface, and if there are any scratches, correct them with an oilstone.
2) Knock a new key into the key groove of the shaft.
3) Assemble the thrust plate.
4) Heat the gear for the specified time at the specified shrink-fitting temperature.
   ★ Cam gear shring-fitting temperature: 200°C
   Heating time: Min.30 minutes
5) Put the timing mark on the outside, then use a hitting tool to press fit until the side face of the gear is in close contact with the shaft flange.
   ★ Knock in quickly before the gear becomes cool.

REPLACING FLYWHEEL RING GEAR

⚠ Take care not to let the flywheel fall.

1. Removing the ring gear

Make a groove on the tooth bottom surface of the ring gear with a grinder, then crack the gear with a chisel.

⚠ Take care in handling the grinder and chisel.

2. Press-fitting the ring gear

1) Check the fitting surface of the ring gear. If any flaw is found, repair it with an oilstone.
2) Heat the ring gear at the specified temperature for the specified time for shrinkage fitting.
   ★ Heating temperature for ring gear:
   Max. 200°C
   Heating time: Min. 50 minutes
3) With the chamfered side of rin gear facing the flywheel, fit it until is side contact the flywheel.